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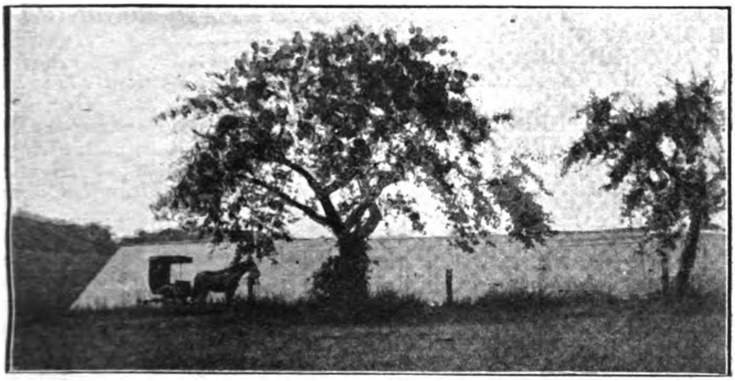
The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 89



SHELTER TENT FOR TOBACCO

SHELTER TENT EXPERIMENT WITH SUMATRA-TYPE TOBACCO

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
JANUARY, 1909

AGRICULTURAL EXPERIMENT STATION
THE PENNSYLVANIA STATE COLLEGE

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 89

SHELTER TENT EXPERIMENTS WITH SUMATRA-TYPE TOBACCO

BY WILLIAM FREAR

Summary.

The Sumatra leaf grown under shelter during the rather favorable season of 1905 at two locations on the Penn Sandy Loam soil, showed:

1. Great diversity of type from commercial seed, but marked uniformity from self-fertilized seed grown in Pennsylvania, 1904.

2. Crops of cured leaf weighing 1,200 and 1,700 pounds per acre.

3. A loss of 21.7 per cent in sweating and assorting.

4. Of sorts, as to quality: 75 per cent of wrapper, of which nearly half were light in color; as to size, 60 per cent of the rather large sizes, over 16 inches in length.

5. Manufacturing test showed high covering capacity, "life," and burning quality superior to that of the 1904 crop, and a general rating above all domestic Sumatra-type tobacco except the better Georgia and Florida grades.

6. The cost of the cured leaf at Cocalico was 45 cents per pound, indicating for the sweated and sorted leaf a cost not exceeding 65 to 70 cents per pound.

Introductory.

In 1902, at the request of the Lancaster County Tobacco Growers' Society, the Station began experiments to determine whether, by the aid of shelter tents such as had been more or less successfully used in Florida and Connecticut, wrapper leaf of the Sumatra type could be produced profitably in Pennsylvania. The peculiar features of this method of culture are the use of slacked or open meshed cheese-cloth shelters,—which exclude the insects, diminish air movements about the plants and increase the moistness of the air,—close planting, high topping, harvesting each leaf separately instead of cutting the entire stalk and curing the leaf before its removal therefrom, and, finally, sweating in bulks rather than in cases. The annual reports of this Station for 1902 to 1904 contain accounts of the earlier experiments. They show that a thinner leaf was secured upon the light Penn sandy loam of the northern townships than upon the Norfolk gravelly loam soil bordering the Susquehanna that was first used for these experiments. The leaf exhibited, when tested in cigar manufacture under factory conditions, some defect in elasticity and burning quality, but yet displayed large covering power, fineness of vein, and good luster. So the experiments have been continued to ascertain how far seasonal differences might affect the quantity and quality of the leaf, how far the defects observed might be diminished by modifications in the selection and culture of the plants; and also to ascertain more accurately the cost of producing such leaf.

The experiments of 1905 were, like those of 1904, made upon the Penn Sandy Loam soil at Milton Grove and Cocalico, on the farms of Messrs. M. Risser and H. D. Burkholder respectively, and, with the exception noted below, upon the same sites. The general local supervision remained, as heretofore, under the care of Mr. M. L. Greider, of Mt. Joy, Vice-President of the Lancaster County Tobacco Growers' Society.

EXPERIMENTS AT MILTON GROVE

The experiments at Marietta having been discontinued, it was decided, upon the urgent recommendation of representatives of the Lancaster County Tobacco Growers' Society, to extend the scope and area of the experiments at Milton Grove. The area covered by the shelter was about doubled, the frame-work from the Marietta shelter being used here so far as needed.

The area of the tent thus enlarged was 78x94.5 feet, equivalent to 7,371 square feet, or a little more than one-sixth of an acre.

The frontispiece affords a side view of the enlarged shelter.

It is not possible, from the data at hand, to prepare an accurate statement of the entire cost of the enlarged shelter.

Preparation of the Soil.

The ground under the old shelter had, as above stated, been planted to tobacco in 1903 and 1904; the newly sheltered ground, in wheat in 1903, in tobacco in 1904.

The old stalks were cleared up and burned off on May 10th and 11th; and, on May 12th, the land was plowed.

The fertilizer used on preceding tobacco crops was a commercial brand rich in available fertilizer constituents, but containing no considerable quantity of organic matter adapted to the formation by its decay of a generous residue of humus. For the 1905 crop, a fertilizer having as its base a large proportion of cotton-seed meal to supply humus, was employed at the following rate per acre:

Cotton-seed meal, 1,350 pounds; carbonate of potash, 200 pounds; dissolved South Carolina rock, 700 pounds; total, 2,250 pounds.

On June 25th this fertilizer was spread broadcast upon the soil, and thoroughly harrowed in.

The Plants and Planting.

The plants used in this place were all grown from seed supplied by the Indian Head Plantations at Tariffville, Connecticut, with the statement that it represented the best strain of the Sumatra leaf that Connecticut had thus far produced.

The plants were grown by Mr. M. L. Greider, at Mount Joy, and on June 5th and 8th were transplanted to the shelter at Milton Grove, and set at about the same intervals as in the preceding years. Very little replanting proved necessary.

Subsequent Cultivation.

The operations of hoeing, weeding, and hunting for worms were promptly and frequently conducted. The first record of suckering is for July 17th. By August 2d, some of the plants were ready for topping. On August 9th, the ground leaves were sufficiently ripe for picking. The main crop, however, did not ripen sufficiently for priming until September 9th, a period of 101 days after the planting of the crop, while later primings of the higher leaves were made on September 14th and 16th, 106 and 108 days respectively after the date of planting.

Weather During the Season.

The weather records for Harrisburg, which may be fairly taken as a basis of judgment for northern Lancaster County temperatures, show that July and September were considerably warmer, June and August slightly cooler, than the normal for twenty years; though if the comparison be confined to the 1901-1905 average, June was slightly warmer, and July, August and September, considerably cooler in 1905.

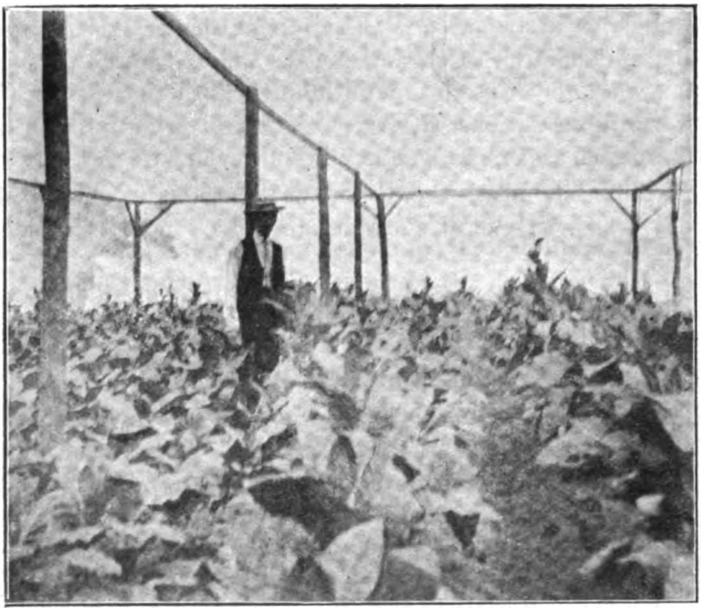

FIGURE 2
Tobacco on New Soil

The rain-fall was measured at Milton Grove during July, August and early September. The records show: July, 5.88 inches; August, 6.83 inches; September 1-16, 2.74 inches.

Considering the rainfalls in June, Ephrata had rain on the 6th and 7th, just after the first planting on the 5th; on the 11th to 13th, a few days after the second planting on the 8th; and another period of light rains from the 21st to the 24th. It is probable that a like distribution of rainfall occurred at Milton Grove, thus favoring the early growth of the plants.

During the latter half of July, there was a rather prolonged rainless period.

In general, the only beating rains of long duration that occurred during the growth of the crop, took place on July 4th and 5th and on August 25th, on the last of which dates the rainfall was nearly four inches. After the first priming, on September 9th, there followed on the 10th and morning of the 11th, a rainfall of 1.19 inches; the remainder of the harvest time was clear.

On the whole, the weather conditions were favorable to growth.

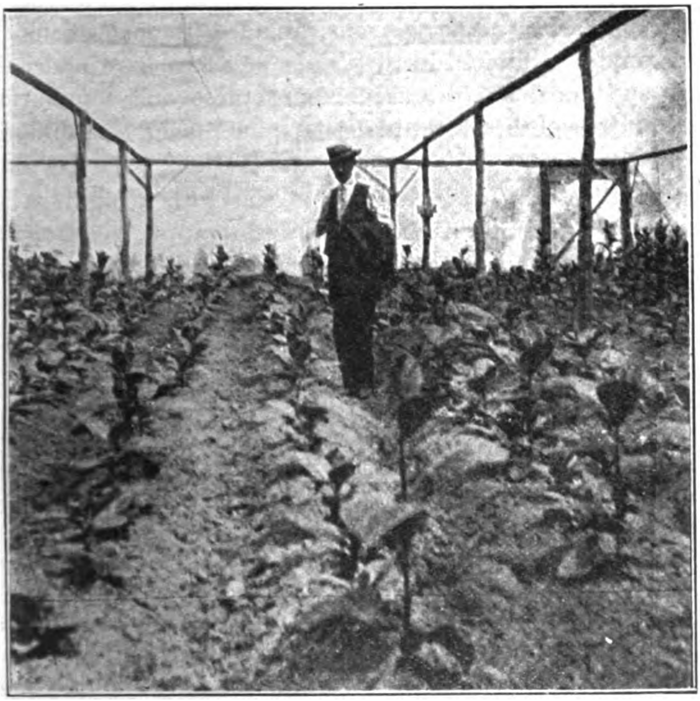

FIGURE 3
Tobacco on Old Soil

Observations During Growth.

Leaf Type. The writer visited the shelter on July 20th. The plants, all produced from selected seed furnished by the Indian Head Plantations, exhibited a great variety of form, as is usual when plants are open to cross-fertilization at the period when the flowers are open. Some of the plants had leaves closely resembling those of the Connecticut seed-leaf variety, instead of following the Sumatra form of their mothers.

Soil Defect. A great difference was observed in the development of the plants on the old and new soils under the shelter. On the old soil, the plants, though taken at the same time and from the same bed as those on the soil newly included under the shelter, were very backward and irregular as compared with the plants on the new soil (although these too were not perfectly uniform). The differences are shown, quite imperfectly, in the accompanying figures (2 and 3).

The soil, though of the light, open Penn sandy loam type, which had, during the two earlier seasons, retained its open, readily cultivable character, exhibited in 1905, over that part used under shelter in 1903 and 1904, an increased compactness and toughness. So tough was the soil that, after planting, hand hoeing was difficult and recourse was had for a time to horse cultivation.

By local top-dressings of the old soil with a highly available commercial fertilizer and by assiduous cultivation, the crop on this land was brought up to equality, later in the season, with that on the new soil, though during most of August the plants on the older soil remained more backward and more yellowish.

The Curing of the Crop.

As in all cases where the leaf is primed, rather than harvested on the stalk according to the usual Pennsylvania practice, the curing proceeded rapidly.

Repairs of Shelter.

It has been noted, in the reports of the experiments from 1902 to 1904, that the cost of keeping the tenting cloth in repair was very slight. In the experiments of those years the weave of cloth used was that known as Ariel Cloth. In this cloth the main web is composed of threads of the same diameter, rather closely woven, with bands, one inch wide, at regular intervals, composed of the same threads much more closely woven to serve for the better support of the entire fabric.

In 1905, however, M. P. A. weave was substituted. This is much more open, admits the sunshine more perfectly, and was chosen with the purpose of securing, if possible, leaf of improved strength and elasticity. The cloth is strengthened by the interweaving, at large intervals, of two parallel cords of much greater diameter and strength than the threads that compose the main fabric. This cloth proved, however, much less satisfactory in point of durability, was subject easily to a displacement of the threads to such extent that openings were formed big enough to permit the entrance of large insects, and was so readily torn that frequent repairs were needed. The expense accounts show items on fourteen days for repair of canvas. The total cost, this season, for keeping in repair the Milton Grove shelter of one-sixth acre area, was $10.43. Computing to an acre basis, the cost would figure $62.58, an exorbitant amount.

Cost of the Shelter-Grown Crop.

An endeavor was made to have kept a complete, detailed record of the cost of the tobacco grown under shelter. To this end it was required that all bills for labor and materials should specify, for each day, the time and materials devoted to each of the several divisions of the tobacco experiments. This direction was not always heeded.

The bills have, however, been painstakingly studied and, after elimination of items for superintendence, board, transportation, etc., that would not be found in the expense statement against any crop privately grown, but are necessary elements of carefully supervised experiments, especially when conducted on a small scale—the principal classes of expenditure have been grouped as follows:

Rent of land, estimated average	$ 50
Rent of one-half the curing shed	15 00
Cost of fertilizer @ $35 per T for the cotton-seed meal, $12.50 for the dissolved rock, and $95 for the carbonate of potash, plus $1 for mixing	6 42
Clearing the land, 18 hours	2 30
Plowing, harrowing and ridging, 8 hours	2 80
Broadcasting the fertilizer, 10 hours	1 50
Planting and replanting, 60¾ hours	7 85
Hoeing and other items of cultivation, 118 hours	15 45
Suckering, 42¾ hours	5 44
Tying up seed-stalks, 1¾ hours	26
Topping, 10¾ hours	1 56
Removing ground leaves, 7 hours	84

Harvesting—Priming, 37½ hours	$5 40	
Hanging up, 16 hours	2 40	
Hauling, 27½ hours	5 62	
Stringing leaves, 78 hours	9 36	
		22 78
Removing canvas from shelter to storage room		2 04
Gathering seed-pods		45
Repair of shelter		10 43
		$95.62

The foregoing statement omits certain important elements of cost, such as depreciation of shelter, cost of lath and cases, and the curing, taking down, sweating and assorting of the leaf.

EXPERIMENTS AT COCALICO

Weather.

The remarks made concerning temperature in connection with the Milton Grove experiments, are applicable also to Cocalico. The rainfall observations at Cocalico in 1905 show: For June 6-30, 2.52 inches in 7 days; for July, 7.17 inches in 15 days, there being during this month at Cocalico no rainless period longer than 7 days; for August, 7.73 inches, in 14 days; September 1-16, 2.92 inches in 4 days. The rainfalls of July 5th (2.68 inches) and August 25th (4.49 inches) were unusually heavy. September, clear weather favored ripening and harvesting. Throughout, the rainfall was heavier at Cocalico than at Milton Grove.

Observations During Growth.

On July 19th the writer visited the shelter and made the following notes:

The soil is light and porous, though moss appears at a few points in the paths between the rows. The plants are growing thriftily. The plants from the Connecticut Sumatra seed (A) were somewhat more mature when transplanted than those from seed (B) (1904 Cocalico Sumatra). These plants have maintained their relative advancement. Many of them have developed flower heads which stand within 18 to 24 inches of the canvas roof of the shelter. Although seed A was represented to be of the best strain of Connecticut Sumatra, purified and freed from light seeds by sifting and blowing, the plants produced, exhibit at Cocalico, as at Milton Grove, a great diversity of leaf form. Many of the leaves are crinkly, have crooked mid-ribs, dark green color and rather coarse veins near the heel of the leaf. Some forms suggest a cross with Connecticut seed-leaf.

The plants from seed B, though not so tall at this time, have a lighter green color, a broad leaf, wide at the heel and tip, straight mid-ribs, veins projecting at a wide angle from the mid-rib and apparently finer than those from seed A.

Curing of the Crop.

On September 22d Mr. Greider reported that the leaf was curing to a uniform color, and that the quality of the average crop would be fully equal to that obtained at Cocalico in 1904, that grown from seed B apparently far better.

On November 29th, the crop having cured satisfactorily, chiefly in the first four weeks after harvesting, it was taken down and packed in cases.

Yield of Cured Crops.

On February 2, 1906, Mr. Greider reported the following weights of cured leaf from the Milton Grove and Cocalico experiments:

	Milton Grove lbs.	Cocalico lbs.
1st pulling	17.5	44.5
2d "	35.5	19.0
3d "	95.0	121.0
4th "	26.0	126.0
5th "	....	52.5
†Extra tops	10.0	*24.0
Sample drawn	7.0	14.0
	191.0	401.0

†Of wrapper grade. *Filler from tops.

The north side of the Cocalico shelter planted with seed A yielded 20 pounds less than the south side planted with seed B.

The yield per acre of cured leaf was: At Milton Grove, about 1,200 pounds; at Cocalico, about 1,700 pounds.

The records of the sweating show that the tobacco was bulked on February 16, 1906, that the temperature rose from 70° F., at the beginning, to 100° F. on February 25th, and then fell to 96° F. on March 2d. On March 3d, the bulk was turned; on the 4th, the temperature was 84° F.; on the 12th, 100° F., and on the 17th had decreased to 92° F. On March 18th, 30 days after the beginning of the sweat, the bulk was taken up and assorted.

Owing to some mixing of leaf from the two Stations, the results of the sweating will be expressed in figures for the combined crops: ;

Weights of Sorts in Pounds.

Lengths (inches)	22	20	18	16	14	12	Total
Light wrappers	11	46	61	28	7½	½	154
Medium wrappers.....	3	22	40	32	11	1	109
Dark wrappers	2	11	25	29	16	13	96
Seconds	1	11	29	31	14	2	88
Totals	17	90	155	120	48½	16½	447

The decrease in weight was from 571 to 447, or 124 pounds, equivalent to 21.7 per cent of the cured leaf. This decrease was caused by some rejection of trash as well as by the sweating process proper. About one-fourth of the cured leaf was graded as "seconds," the balance as "wrappers:" 43 per cent light, 30 per cent medium, and 27 per cent dark. That is to say, the grading shows as high quality as that exhibited by the earlier crops on the Penn sandy loam soil. The general tendency was to large-sized leaves, 60 per cent being over 16″ long.

Tests of the Sumatra Leaf.

The Cocalico leaf from seed B was, when sweated, distinctly lighter in tint than that from seed A, but fully equal to it in elasticity.

A factory test was arranged, but no written report was returned. A verbal statement was made unqualifiedly preferring the leaf submitted (Cocalico B) to the average Connecticut Sumatra and to all but the better Georgia and Florida sorts. The covering capacity was excellent, fully equal to that reported for the 1904 crop. The leaf showed more life, and a better burn, in some tests made by the writer, than the 1904 leaf showed. The percentage of cigars burning crooked was no greater than that found on most 5-cent grades of cigars.

Cost of Cured Leaf, Cocalico.

Rent of land @ $60 per acre valuation		$ 75	
Rent of shed (½)@ $400 value: 10 per cent.		20 00	
Cost of fertilizer		3 61	
Plowing and harrowing, 8 hrs		2 10	
Putting on the canvas, 73½ hrs		10 89	
Applying fertilizer, 6½ hrs		99	
Planting, 27 hrs		3 96	
Cultivating, 27½ hrs		4 48	
Topping, 8 hrs		1 25	
Covering seed heads		50	
Suckering, 45½ hrs		6 77	
Harvesting—			
Priming, 132½ hrs	$21 65		
Hauling, 29½ hrs	6 68		
Stringing, 116½ hrs	14 51		
Hanging up, 35 hrs	5 07		
		47 91	
Cost of cases, set up and lined		7 62	
Taking down and packing cured leaf, 30 hrs.		4 52	
			$115.35
Depreciation—			
Canvas (½ cost)	$33 11		
Frame: materials and labor (1/10 cost)	8 29	41 40	41 40
			$156 75

It is believed that these Cocalico figures represent more nearly than those from the Milton Grove experiments the probable cost of producing tobacco of this type under shelter. Certain items of hauling and of interest on shelter investment have not been included, but they will but slightly affect the result. The annual interest on the cost of the shelter ($160.41)@ 5 per cent would be $8.02. The crop of cured leaf at Cocalico weighed 408 pounds. Hence the cost, ready for sweating, would not exceed 45 cents. The loss of weight during the sweating and assorting being assumed to be about one-fifth, the value per pound of the residue would be increased to 56¼ cents. The Connecticut packers charged 20 cents per pound for sweating and assorting. This item can be greatly reduced by recourse to Pennsylvania packers, once the latter shall have studied the special needs of this type of leaf. The cost of production will probably, therefore, not exceed 65 to 70 cents per pound. The yield per acre may reach as high as 1600-1700 pounds of cured leaf. Under these conditions and with the present market prices of Sumatra leaf, there is room for handsome profit from the application of skill and enterprise to the culture of this type of tobacco.

The chances for success are, of course, conditioned by the rapid development of the Florida culture of Sumatra-type, shelter-grown leaf, and upon the conduct of the business with enough capital to secure the necessary skilled help and to make the requisite fixed investment, and upon a large enough scale to form an attractive market.

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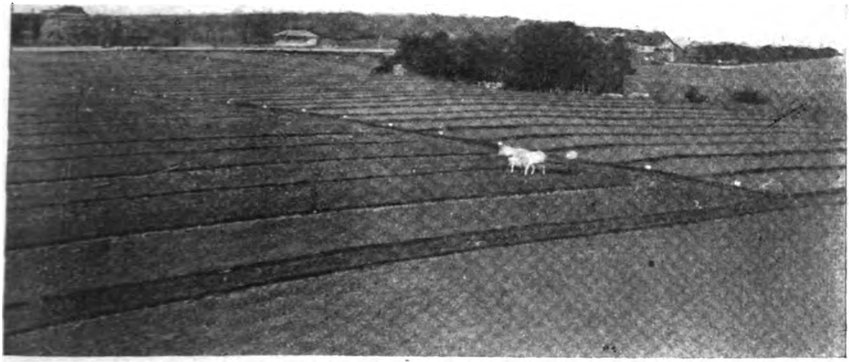

General View of Fertilizer Plats

SOIL FERTILITY

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
MARCH, 1909

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The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 91

SOIL FERTILIZATION

JOHN P. STEWART

SUMMARY

1. Fertilizers are but one of several factors that affect success in orcharding. The others include varieties, location, soil management, spraying, pruning and general orchard care.

2. The best orchard treatment probably consists in the discovery of the crop-limiter, the elevation of it to the level of the other factors, and the maintenance of a proper balance in the treatment thereafter.

3. In some orchards fertilizers and manures are the limiting factor, while in others it is something else. Hence, in general, it is questionable whether they should be applied in large amounts, until the orchardist has evidence that they are needed.

4. The need of a fertilizer is indicated by the trees being deficient in growth, foliage, or fruit, after the other factors are apparently right. Under these conditions applications of manures and fertilizers can scarcely fail to produce beneficial results.

5. The indications are that nitrogen has more value as an orchard fertilizer than is generally accorded it. It should be used judiciously, however, on account of its effect on color. It can be used most freely on the earlier soils or in localities with rather long growing seasons. It is probable that failure to secure results on apples from the application of potash and phosphates may often be

phosphate for oats, and 7 to 10 tons of manure and 160 to 200 lbs. acid phosphate to the wheat. No manure is applied to the oats and no fertilizer of any kind to the clover and timothy until in the winter or early spring, when the manure is applied to the sod in preparation for the potato crop which is to follow.

Test in 1908.

Early in August, 1907, the oat plat was plowed. Manure was applied on the plowed ground August 19, at the rate of 10 tons per acre. The land was harrowed a number of times before sowing and the wheat was sown September 6. The rate of seeding was 2 bushels per acre, and acid phosphate was applied at the rate of 160 lbs. per acre. Each plat consisted of two drill widths extending across the field and was 141½ feet by 12 feet and comprised .0392 acre. All the varieties was sown twice in the same order. That is, the whole list of varieties was sown one variety after another and then a new series was sown in the same order. The average yield of the duplicate plats was taken as the yield of each variety.

Oct. 7, Fultzo-Mediterranean, Eclipse and Wyandotte Red, the seed of which had been obtained from the Maryland Station, were sown in another field, and Reliable was sown with them as a check. On account of the late sowing these did not yield well. However, their yields are given in the table with the others, and also their "corrected yields." In computing the corrected yields we assumed that if they had been sown with the other varieties they would have yielded as well compared with Reliable as they did when sown late. This, however, may not be strictly true, but it enables us to compare their yields with those of the other varieties. Funk's Turkey Red is also a new variety that has been added to the list. It is a standard red wheat of the West. The seed of Royal Red Clawson was lost. This is one of the best yielding varieties that have been tested. The "'Wheat No. 1" has been grown as "Mortgage Lifter," but it was found that it was not true to name. However, it was retained and its yields are given with those of the others.

The climatic conditions were more favorable for wheat than usual and a good crop resulted, the yields being considerably above the average. There was scarcely any winter injury and practically no loss from the Hessian fly.

The wheat was cut July 11, and threshed July 17.

Yields of Varieties of Wheat in 1908.

VARIETY	YIELD PER ACRE		Weight per struck bu. lb.
	Grain, bus. (60 lb.)	Straw, lb.	
1. Reliable	37.2	4114	57.25
2. Ontario Wonder	32.6	4083	59.03
3. Harvest Queen	36.4	4046	58.00
4. Dawson's Golden Chaff	43.5	3942	58.56
5. Dietz's Longberry Red	37.4	4022	59.25
6. Fultz	34.4	3277	58.03
7. Beechwood Hybrid	36.5	3755	58.69
8. Forty Fold or Gold Coin	37.6	3892	59.00
9. Turkish Amber	38.2	3884	59.91
10. Rochester Red	37.6	3920	58.88
11. Rural New Yorker No. 6	34.7	3331	58.00
12. Funk's Turkey Red	31.4	3230	59.91
13. Fulcaster	37.7	3850	59.16
14. Harvest King	36.1	3590	59.88
15. Martin Amber	37.4	3709	59.16
16. Rural New Yorker No. 57	29.2	4007	60.25
17. Jones' Longberry No. 1	33.0	4489	59.00
18. China	32.4	4420	59.16
19. Wheat No. 1	34.8	3798	59.88
20. *Fultzo Mediterranean	30.8	3896	
21. *Eclipse	34.7	3511	
22. *Wyandotte Red	41.2	3136	
** Reliable	22.5	1944	
** Fultzo Mediterranean	18.6	1841	
** Eclipse	21.0	1659	
** Wyandotte Red	24.0	1842	

* Corrected yields of these varieties.

** Actual yields of these varieties. They were sown Oct. 7 ; the others Sept. 6.

Test in 1909.

After the oat crop of 1908 was removed, the land was plowed August 5. Manure was applied August 17, at the rate of about 6 tons per acre. The ground was harrowed and rolled a number of times and the wheat was sown September 1 and 2. The rate of seeding was 2 bushels per acre and acid phosphate was applied at the rate of 160 ℔s. per acre.

Instead of sowing the varieties in duplicate plats as formerly. Wheat No. 1 was sown as a check variety on every third plat to the twenty-second plat and on every fourth plat from that on, and only one plat of each of the other varieties was sown.

The ground was rather dry when the wheat was sown and continued dry all fall, no rain falling in September, only 2.67 in. in October, and only .8 in. in November, and so the wheat did not get as good a start as usual. The fly did more damage than generally, owing no doubt to the early sowing and the lateness of the first frosts. The injury due to the fly will be given later.

The wheat was cut July 12, and threshed July 21.

Two other varieties were grown this year, Currell's Prolific and Councilman. The seed of these was obtained in 1907 from the Maryland Station.

In the table giving the results of the tests in 1909, there are given the "corrected yields," and a word of explanation should perhaps be added in regard to these. The check variety which comes at regular intervals is a "check" on the productive power of the soil, and it is assumed this is indicated by the variation in the yield of this variety. Then the difference between two check plats is assumed to be a gradual one, and if the check variety had been sown on the intervening plats its yield would have gradually increased or decreased. The average yield of Wheat No. 1 is taken as the corrected yield of this variety. It is assumed then that the yield of each variety is to the average yield of Wheat No. 1 as the actual yield of the variety in question is to the assumed yield of the check variety on that same plat.

Yields of Varieties of Wheat in 1909.

VARIETY	ACTUAL YIELDS PER ACRE		CORRECTED YIELDS PER ACRE		Weight per struck bu.
	Grain, bus. (60 lb.)	Straw, lb.	Grain, bus. (60 lb.)	Straw, lb.	
1. Wheat No. 1 (check).....	28.5	2705	28.6	2756	61.1
2. Reliable	25.4	2616	27.0	2820	61.5
3. Ontario Wonder	28.2	2583	31.9	2953	61.8
4. Wheat No. 1............	23.7	2280			
5. Harvest Queen	24.5	2806	27.4	3168	58.6
6. Dawson's Golden Chaff..	31.6	2244	31.5	2383	59.4
7. Wheat No. 1............	29.3	2788			
8. Dietz's Longberry Red...	29.3	3350	29.5	3202	62.3
9. Fultz	28.3	4236	28.0	3894	61.5
10. Wheat No. 1............	28.7	3118			
11. Beechwood Hybrid	32.2	3588	31.4	3467	61.4
12. Forty Fold or Gold Coin..	28.4	2428	27.2	2588	59.9
13. Wheat No. 1............	30.4	2318			
14. Turkish Amber	31.5	3974	31.2	4544	62.3
15. Rochester Red	29.1	3229	30.5	3557	60.3
16. Wheat No. 1............	25.7	2594			
17. Rural New Yorker No. 6..	25.5	1794	28.1	1990	59.9
18. Funk's Turkey Red......	19.8	3229	21.5	3707	61.6
19. Wheat No. 1............	26.6	2263			
20. Fulcaster	29.0	3229	30.9	3964	62.8
21. Harvest King	32.5	2898	34.3	3600	62.3
22. Wheat No. 1............	27.4	2208			
23. Martin Amber	30.1	4002	30.5	4677	62.5
24. Rural New Yorker No. 57.	24.6	3229	24.3	3548	61.3
25. Jones' Longberry No. 1..	34.8	3449	33.4	3576	61.3
26. Wheat No. 1............	30.7	3808			
27. China	35.2	5326	32.3	3949	61.0
28. Currell's Prolific	31.6	3919	28.5	2985	61.6
29. Councilman	29.9	3449	26.6	2696	61.8
30. Wheat No. 1............	32.8	3422			
31. Wyandotte Red	35.1	4526	31.0	3814	63.0
32. Eclipse	31.2	3229	27.9	2854	61.6
33. Fultzo Mediterranean....	29.7	2925	27.0	2718	61.5
34. Wheat No. 1............	31.1	2815			
35. Spring	24.4	3781	22.7	3910	60.0
36. Funk's Turkey Red...... (1½ bu. per acre.)	27.6	3726	26.1	4088	61.6

Average Yields of Varieties.

Dawson's Golden Chaff gave the highest yield of grain in 1908, but was fifth in the list in 1909. Harvest King headed the list in 1909, while it was only tenth in 1908. From this it can readily be seen that the relative merits of a variety cannot be determined by a test of only one year, but must be based on the average yield for a number of years. Accordingly there are given two tables showing the average yields for the last four years, and the average yields for all years tested respectively. In both tables Reliable is used as a standard and the increase (or decrease) over that variety is given.

Average Yields of Varieties for Four Years, 1906-1909.

VARIETY	YIELD PER ACRE		Increase (or decrease) over Reliable		Wt. per struck bu., lb.
	Grain, bus. (60 lb.)	Straw, lb.	Grain, bus. (60 lb.)	Straw, lb.	
Reliable	32.6	3757			60.87
Ontario Wonder	32.5	3771	- .1	14	61.46
Harvest Queen	31.9	3370	- .7	-387	58.90
Dawson's Golden Chaff	36.4	3153	3.8	-604	59.44
Dietz's Longberry Red	31.9	3676	- .7	-81	61.84
Fultz	31.1	3607	-1.5	-150	61.26
Beechwood Hybrid	33.3	3678	.7	79	61.10
Forty Fold or Gold Coin	33.1	3511	.5	-246	59.68
Turkish Amber	33.4	4191	.8	434	61.93
Rochester Red	33.1	3852	.5	95	60.17
Rural New Yorker No. 6	30.4	3181	-2.2	-576	59.68
Fulcaster	33.8	4129	1.2	372	61.74
Harvest King	34.0	3471	1.4	-286	61.71
Martin Amber	32.4	3808	- .2	-51	61.92
Rural New Yorker No. 57	28.2	3429	-4.4	-328	61.38
Jones' Longberry No. 1	32.3	3888	- .3	131	60.76
China	32.9	4065	.3	308	61.04

Average Yields of the Varieties of Wheat for all Years Tested, Omitting 1904, Compared with Reliable.

	Yield Per Acre		Increase (or decrease) per acre over Reliable		Wt. per struck bu., lb.
	Grain, bus. (60 lb.)	Straw, lb.	Grain, bus. (60 lb.)	Straw, lb.	
19 Years—1890-1909					
Reliable	30.9	3672			62.1
Ontario Wonder	29.7	3181	-1.2	-491	61.7
Dietz's Longberry Red	29.8	3587	-1.1	-85	62.3
Fultz	28.4	3360	-2.5	-312	61.8
Fulcaster	31.7	3887	0.8	215	62.5
13 Years—1896-1909.					
Reliable	29.9	3216			62.1
Forty Fold or Gold Coin	30.2	3022	0.3	-194	60.7
Rochester Red	29.4	3246	-0.5	30	60.4
12 Years—1897-1909.					
Reliable	29.9	3412			62.1
Dawson's Golden Chaff	31.4	3152	1.5	-260	59.7
10 Years—1899-1909.					
Reliable	29.2	3608			62.1
Harvest Queen	27.2	2898	-2.0	-710	59.3
Harvest King	30.3	3127	-1.1	-481	61.8
9 Years—1900-1909.					
Reliable	29.6	3167			62.1
Beechwood Hybrid	28.6	3149	-1.0	-18	61.6
8 Years—1901-1909.					
Reliable	30.5	3251			62.1
Martin Amber	29.0	3204	-1.5	-47	62.0
Rural New Yorker No. 57	28.6	3030	-1.9	-221	61.7
Jones' Longberry No. 1	29.6	3197	-0.9	-54	61.3
Rural New Yorker No. 6	28.6	2755	-1.9	-495	59.7
7 Years—1902-1909.					
Reliable	31.3	3231			62.1
Turkish Amber	31.4	3343	0.1	112	62.2
5 Years—1904-1909.					
Reliable	30.8	3631			62.1
China	31.5	3701	0.7	70	60.8
2 Years—1908-1909.					
Reliable	32.1	3467			62.1
Fultzo Mediterranean	28.9	3307	-3.2	-160	61.5*
Eclipse	31.4	3182	-0.7	-285	61.6*
Wyandotte Red	36.1	3475	4.0	8	63.0*
Funk's Turkey Red	26.5	3468	-5.6	-1	60.7
1 Year—1909.					
Reliable	28.6	2920			62.1
Currell's Prolific	28.5	2985	-0.1	165	61.6
Councilman	26.6	2696	-2.0	-124	61.8

* Weight per struck bushel for 1909 only.

TABULAR DESCRIPTION OF VARIETIES.

	Bearded or smooth	Color of grain	Color of chaff	Color of upper part of straw	Height in inches, av'age for 1908 & 1909	Injury from fly 1909, per cent*	Date of ripening, 1909	REMARKS
Reliable	Bearded	Red	White	Light yellow	50	2.00	July 12	Rather weak in the straw and likely to lodge. A good yielding variety.
Ontario Wonder	Smooth	"	"	" "	52	4.00	14	Rather weak in the straw.
Harvest Queen	"	White	White	Light yellow	49	6.00	13	Straw stiff, seldom lodges.
Dawson's Golden Chaff	"	"	Brown	" "	49	2.50	13	Very stiff straw, the highest yielding variety.
Dietz's Longberry Red	Bearded	Red	White	Purple	52	2.50	12	Straw only medium stiff.
Fultz	Smooth	"	"	Light purple	53	4.00	10	Straw rather weak.
Beechwood Hybrid...	"	"	Brown	Purple	51	1.50	12	Straw medium stiff.
Forty Fold or Gold Coin	"	White	"	"	51	5.00	10	" " "
Turkish Amber......	Bearded	Red	White	"	52	4.00	10	Straw rather weak.
Rochester Red	Smooth	"	Brown	"	52	2.00	14	Straw stiff.
Rural New Yorker No. 6	"	"	"	"	51	8.00	12	" "
Funk's Turkey Red..	Bearded	"	White	White	40	5.00	12	Straw medium stiff, very short. Grains small.
Fulcaster	"	"	"	Light purple	48	1.50	12	Straw medium stiff, often lodges. A very good variety.
Harvest King	Smooth	"	Brown	" "	47	2.50	12	Straw stiff.
Martin Amber	"	"	"	Purple	46	2.25	9	Straw medium stiff.
Rural New Yorker No. 57	Bearded	"	White	Light yellow	49	10.50	12	Straw stiff. Chaff fuzzy.
Jones' Longberry No. 1	"	White	Brown	" "	51	4.00	14	Straw fairly stiff.
China	Smooth	Red	"	Purple	48	2.00	13	Straw fairly stiff.
Fultzo Mediterranean	"	"	White	"	42	2.25	10	Straw stiff.
Eclipse	Bearded	"	Brown	Light yellow	49	1.50	14	Straw fairly stiff.
Wyandotte Red	Smooth	"	White	Purple	51	1.50	10	" " "
Councilman	"	"	Brown	"	48	2.00	10	Straw rather weak.
Currell's Prolific.....	"	"	"	"	51	3.60	11	Straw fairly stiff.

* Percentage of stems infested in the spring, not taking into account those that had died during the winter.

Summary.

The highest yielding varieties according to the averages for the last four years are in order of rank as follows:

Dawson's Golden Chaff
Harvest King
Fulcaster
Turkish Amber
Beechwood Hybrid
Rochester Red
Forty Fold or Gold Coin
China
Reliable

According to the averages for all years tested for five or more years the order is as follows:

Dawson's Golden Chaff
Fulcaster
China
Forty Fold or Gold Coin
Turkish Amber
Reliable
Rochester Red
Jones' Longberry No. 1
Beechwood Hybrid

Of these varieties Dawson's Golden Chaff, Forty Fold or Gold Coin and Jones' Longberry No. 1 are white and the remainder red.

Dawson's Golden Chaff, Harvest King and Rochester Red may be safely recommended for rich land because of their stiff straw which prevents their lodging. Fulcaster is one of the very best varieties both in yield and quality of the grain. but it often lodges when sown on low land.

Preliminary milling and baking tests indicate that Dawson's Golden Chaff is inferior in quality to Fulcaster.

Effect of Date of Sowing Upon the Yields.

The effect of the date of sowing upon the yield of wheat was discussed in Bulletin No. 82. In 1907, Reliable wheat was again sown at intervals of 10 days, beginning August 18, and ending October 27, just as was done in the autumn of 1906. Eight sowings were made on plats each a little over one-twenty-fifth of an acre in size. No check plats were sown, but the land was apparently very uniform.

Below are given the yields for the different dates of seeding in both 1907 and 1908, together with the per cent. of stems for each seeding that were infested by Hessian fly.

Another table shows the deficiency or excess in temperature and rainfall for the years 1906 and 1907 by weekly periods from August 6 to December 31.

Different Dates of Sowing.

Date Sown	Infested by fly, per cent. of stems		1907		1908	
	1907	1908	Yield grain, bus. (60 lb.)	Yield straw, lb.	Yield grain, bus. (60 lb.)	Yield straw, lb.
Aug. 18	31.0	6.7	26.8	3143	26.8	3519
28	12.5	4.7	30.3	3455	33.8	3650
Sept. 7	5.7	4.0	32.1	4511	27.9	3561
17	6.3	None	32.0	4345	28.8	3504
27	Very few	"	30.9	3243	19.6	2167
Oct. 7	None	"	32.9	2692	19.5	1281
17	"	"	30.9	2726	19.7	1324
27	"	"	28.1	2333	14.0	1608

Table Showing Deficiency or Excess of Temperature and Rainfall in 1906 and 1907, by Weekly Periods, from Aug. 6 to Dec. 31.

(From the crop reports in Annual Reports, 1906-1907 and 1907-1908.)

PERIODS	1906		1907	
	Temperature, degrees	Rainfall, inches	Temperature, degrees	Rainfall, inches
Aug. 6-12	2.8	1.04	2.8	.35
13-19	.7	- .53	- .1	- .66
20-26	4.5	- .72	-2.4	.28
27-Sept. 2	.6	.39	-2.6	- .67
Sept. 3-9	1.0	.50	2.0	1.26
10-16	5.6	- .12	1.6	1.14
17-23	7.5	- .27	3.1	1.00
24-30	1.8	- .31	-2.8	.02
Oct. 1- 7	-2.6	- .16	5.0	.31
8-14	-12.4	.78	-6.6	.29
12-21	3.1	1.67	-5.1	- .53
22-28	4.1	- .19	-3.8	.30
29-Nov. 4	-7.5	- .39	-4.3	.80
Nov. 5-11	- .9	- .30	- .9	- .08
12-18	-4.6	.01	-7.8	- .26
19-25	7.1	- .58	2.0	- .14
26-Dec. 2	5.6	- .56	1.9	- .28
Dec. 3-9	-3.3	.21	-1.6	- .40
Dec. 10-16	2.2	- .12	-1.3	.73
17-23	-6.5	.29	- .3	.19
24-31	- .3	.50	9.2	- .41

Usually there is a rather long interval during which the time of seeding has very little effect upon the yield. The dangers from early sowing are due chiefly to the ravages of the fly and of late sowing to the inability of the wheat to get a good growth before the cold weather comes. The Hessian fly is a rather uncertain factor, some years doing scarcely any damage and other years causing a serious loss. As is well known, the eggs are not laid after the first heavy frosts, and even cool weather without frosts seems to kill off the adults. In the table it can be seen that the fly pupae were most abundant in the earliest sown wheat, and gradually decreased in the later seedings until none could be found. They were much more abundant, it will be noticed, in the fall of 1906 than in the fall of 1907. In 1906 the first autumnal frosts were October 8 and 12, and no injury was done by the fly in the wheat sown October 8, though there was slight injury in that sown September 27. In 1907, the first autumnal frost was October 9, but there was no injury from the fly in that sown September 17, which was up some time before the first frost came.

In 1907 the wheat sown October 8 gave the highest yield of grain, and that sown September 8 the highest yield of straw. In 1908 that sown August 28 gave the highest yields of both grain and straw.

There can be no doubt that the late seeding in the fall of 1906 yielded comparatively well because the early seeding was injured so much by the fly. Then, also, there were a number of weeks in October and November that were warmer than the average, which permitted the late sown wheat to get a good growth. In the fall of 1907 the small injury by the fly and the warm weather and timely rains in September favored the early seeding, while the cool weather through October and the first half of November, checked the growth of the later seeding.

8.4 ℔s. butter-fat, loss in skimmilk and 2.4 ℔s. butter-fat loss in buttermilk, gives 10.8 ℔s. butter-fat loss in both.

10.8 ℔s. butter-fat from 400 ℔s. butter-fat leaves 389.2 ℔s. of butter-fat to be churned into butter.

If 389.2 ℔s. butter-fat is churned into butter containing 14% water and 4% salt and casein, it will make 474.6 ℔s. of butter.

474.6 ℔s. less 400 ℔s. gives 74.6 ℔s. of butter, which is the over-run.

74.6 ℔s. of butter times 100 makes 7,460 divided by 400 gives 18.6% over-run.

Hand Separator Creamery

Example:

1,600 ℔s. of cream testing 25% contains 400 ℔s. of butter-fat.

1,600 ℔s. less 400 ℔s. of butter-fat leaves 1,200 ℔s. of buttermilk.

.2% loss in churning gives 2.4 ℔s. butter-fat lost.

400 ℔s. of butter-fat less 2.4 ℔s butter-fat gives 397.6 ℔s. of butter-fat to be churned into butter.

If this amount of butter-fat is churned into butter which contains 14% water, and 4% salt, casein, etc., it will make 484.8 ℔s. of butter.

484.8 ℔s. less 400 ℔s. gives 84.8 ℔s. of butter, which is the over-run.

84.8 ℔s. times 100 is 8,480 divided by 400 gives 21.2% over-run.

Some of the contestants occasionally secured a satisfactory over-run, but none seemed to be able to control it and hold their over-run uniformly high. In the August contest, the lowest over-run was 9.4%, while the highest was 24%.

The contest work as a whole suggests that just as good butter can be made in Pennsylvania as anywhere; that much of it can be made better, and greater economy can be practiced; that an increasing number of buttermakers are realizing that there is room for improvement, and they are desirous of securing it, and of using every help to attain the best results for their employers and themselves.

The willingness to learn is the first step toward improvement; modern equipment and methods soon follow.

THE PENNSYLVANIA STATE COLLEGE AGRICULTURAL EXPERIMENT STATION

LIST OF PUBLICATIONS

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Reports 1897, 1898-9, 1899-1900, 1900-1, 1901-2, 1902-3, 1903-4.

Bulletin 37. The Peach Industry in Pennsylvania.
" 46. Variety Tests of Wheat.
" 47. Tests of the Sugar Beet in Pennsylvania.
" 48. Winter vs. Spring Bran.
" 49. Field Fertilizer Experiments on Tobacco.
" 50. Distillery Waste: Miscellaneous Cattle Food Analysis.
" 52. Rye Meal and Quaker Oats Feed for Milk Production.
" 53. Methods of Steer Feeding.
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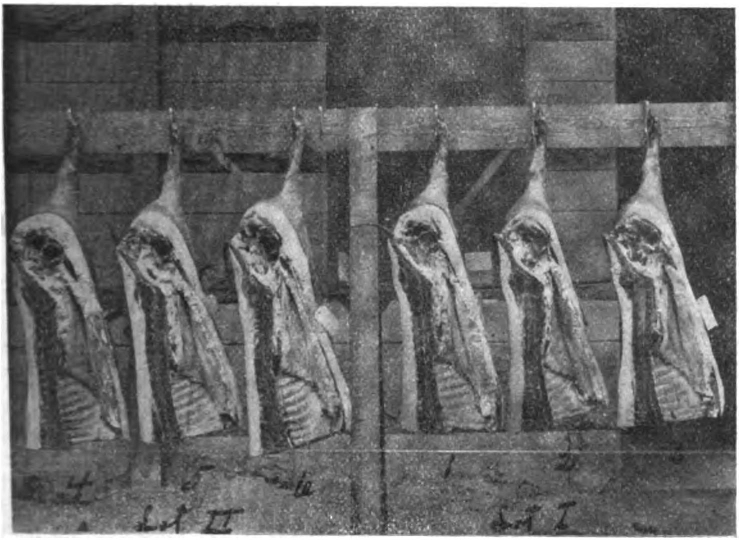

EXPERMENTS IN PIG FEEDING

WHITE MIDDLINGS VS. CORN CHOP AND TANKAGE

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
DECEMBER, 1909

Oct 7, 1936
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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 95

REVISED

EXPERIMENTS IN PIG FEEDING

White Middlings vs. Corn Chop and Tankage

By T. I. MAIRS and S. W. DOTY

CONCLUSIONS

1.—Pigs on a ration of middlings alone made better use of their feed at first than those on a ration of corn chop. (corn meal) and tankage, but later the exact reverse was the case.

2.—The pigs on the exclusive middlings ration were not as active and healthy as those on corn chop and tankage, neither did the former eat with the relish that did the latter.

3.—Pigs on corn chop and tankage (3 to 1) made much better growth and development throughout the experiment. The three pigs on middlings made only a total gain of 337.5 pounds while those on corn chop and tankage gained a total of 448.5.

4.—Neither ration proved profitable for growing and fattening pigs at the prices named. The corn chop and tankage had a slight advantage. With corn chop at an average price the latter ration should be used to good advantage. Middlings, however, when fed alone proved to be an undesirable, unappetizing and unprofitable ration when fed for any length of time.

5.—The hogs fed corn chop and tankage dressed out a noticeably better percentage.

6.—The dressed carcasses showed no appreciable difference as to the relative proportion of lean to fat or as to condition of either.

7.—Probably the one chief feature brought out in the test was the ability of the pigs on corn chop and tankage to consume larger quantities of feed with a relish and make much better growth and development in every way.

A Comparison of White Middlings With a Mixture of Corn Meal and Tankage for Growing and Fattening Pigs.

Pork as well as beef or mutton can be produced profitably or unprofitably; which it will be, leaving out of consideration the individual, depends almost entirely upon the feed used and the care and management of the feeder. Besides the production of pork economically another important consideration of the producer is the influence of the feed upon the product. Different feeds have different effects upon the condition of the carcass. It has been found that food is one of the important factors in determining the firmness or softness of the flesh and fat of pork.

Corn, as is well known, has always been the standard food for hogs. It has been the basis of a majority of rations for growing and fattening swine and in some sections of the country often makes up the whole ration. This, however, has been found unprofitable and would be especially so with corn at the present price. Aside from this corn alone is too fattening a food for growing pigs and it is necessary to supplement it with some one or more of our many feeds rich in protein in order to bring about growth and bone development. Of these highly nitrogenous feeds tankage has been found to be one of the best for balancing up the swine ration and is rapidly gaining in favor with the pork producer. Middlings is another important feed to be considered by the swine grower. In fact it has come to have an unsurpassed reputation for hog feeding, especially for young animals in the early stage of fattening. The Wisconsin Experiment Station has done some work in the ways of comparing corn and middlings. It was found that when the two were used together in the same ration gains were produced 20% more economically than with middlings alone, and also that middlings were a more profitable feed than corn when fed alone. It is usually the case that when feeds are combined properly they make a more palatable feed and one that can be fed with the least waste of material and energy and produce the best effects upon the carcass. This is the problem the producer has to face.

Thesis of W. H. Morgan.

During the winter and spring of '07 and '08 Mr. W. H. Morgan, a senior student, took for his thesis an investigation of the influences of different feeds upon the carcass of animals. It was thought advisable to summarize briefly this work in connection with the experiment herein discussed as the two are somewhat similar in their results.

Mr. Morgan carried on his work with two lots of pigs of two each. He fed one lot a ration consisting of corn chop 76% and tankage 24% while the other lot received the following ration: Corn chop 70% and oil meal 30%. The object was to determine the effect of these feeds upon the condition, growth and appetite of the animals, and the effect upon the dressing percentage and the general condition of the carcasses as shown after slaughter. The latter has relation principally to the relative proportion of fat and lean in the carcass and the condition of same.

This test was carried on practically the same as the one herein described. It is to be criticized, however, in having only two pigs in each lot. The results from experiments carried on with so few animals are not to be considered conclusive as a rule, since there is too much of a chance for individuality to affect the results.

The points of interest in this test as observed and set down by Mr. Morgan are in brief as follows:

"(1) The tankage fed lot handled better and had finer and silkier coats than the oil fed lot.

(2) The bones and framework of the oil meal fed lot increased but little during the experiment while the tankage fed lot increased rapidly in these respects.

(3) The tankage fed lot made the greater gain in lean meat. The oil meal lot gained well in fat but their frame and lean meat did not increase in proportion as did the other lot.

(4) The flesh of the tankage lot was firmer than that of the oil meal lot.

(5) The tankage fed lot ate heartily and with a relish throughout the experiment. It took the oil meal lot two weeks to get on full feed, and then they did not eat with a relish, and at the close of the test they were consuming not quite half as much feed as the tankage fed lot.

(6) The tankage fed lot dressed out 77.5%.
The oil meal fed lot dressed out 74%.

(7) The back and leaf fats of the tankage fed lot had a higher melting point than that of the oil meal fed lot.

(8) The tankage fed lot made a total gain of 350 pounds or an average daily gain of .91 pounds at a cost of $5.10 per 100 pounds. The oil meal fed lot gained a total of 202 pounds or .525 pounds per day at a cost of $5.44 per 100 pounds."

Thus it is seen that the results were quite in favor of the use of tankage over oil meal when fed in connection with corn as a food for growing and fattening pigs. The two rations had the same nutritive ratios and aside from feed the two lots were subjected to the same treatment as nearly as possible but with results noticeably different as seen above. The fact that the results of this test are so decisive and that the two pigs of each lot bore out the results so nearly alike, it might seem that the small number of animals could be overlooked to a certain degree. The test is one more argument in favor of tankage as a feed for swine when fed with corn chop.

Plan of Experiment.

With the hope of learning something of interest relative to a comparison of white middlings with a mixture of corn meal and tankage for growing and fattening pigs, an experiment was planned for 1908-9.

Two lots of pigs of three each were selected for this test. The pigs were pure bred Cheshires, all of the same litter and were fourteen weeks of age at the time the test was begun. Up to November 10th the pigs were subjected to the same treatment, having been weaned only one week. On this date they were divided into two lots, as nearly equal in quality and weight as possible, there being two sows and one barrow in each lot. At this time they were also put on the experiment ration in order to accustom them to the feed before beginning the test. On November 17th the pigs were weighed and the experiment proper was begun. The pigs were weighed at the same time each week during the experiment and careful record kept of the individual weights. The experiment lasted seventeen weeks closing March 16th.

Feed.

The pigs were fed twice daily. Each feed was weighed dry at each feeding time and placed in the trough when sufficient water was added to make a moderately thick slop. The amount of feed fed was governed by the appetites of the pigs in each lot; each being fed all it would eat up readily. The pigs did not have the run of an open yard except for a few days during the latter part of the experiment. There is a small open shed with a plank floor adjoining the pen which the pigs had access to most of the time.

The feeds used were white middlings of good quality costing $30 per ton, corn chop of good average quality costing $34 per ton, and feeding tankage at $28 per ton. The above are the actual prices paid for the feed delivered at the Station barn.

Wheat middlings are classified as brown or standard middlings and white middlings. The latter contain a higher percentage of protein and more total digestible matter and for that reason were used in this test. Middlings are essentially a feed for swine, and no other feed is better for swine at all ages than middlings when fed in proper quantities. They may make up the sole ration of pigs before weaning and a considerable portion of the ration for growing pigs. It is well brought out in this experiment, however, that they are an incomplete and unprofitable feed when fed alone to growing and fattening hogs.

Feeding tankage is a by-product of the packing house. It is made from various waste products such as meat scraps, fat trimmings, etc. These are put in a tank and subjected to excessive heat for several hours, when the grease is removed and the residue dried. This latter is ground and put on the market as tankage. Tankage varies greatly according to what is tanked. Some is fit for fertilizer only and is sold as such, but the better grades are sold for feeding purposes. Tankage like other by-products from the slaughter houses is very rich in protein and for that reason is a highly concentrated food and must be fed with care. Its chief use has been in feeding swine, generally being fed in connection with corn, and it has been found very profitable even when the tankage is worth 30% to 40% more per ton than corn. Owing to the richness of this feed, most authorities recommend from 10% to 15% of tankage in the ration. In this test, however, the ration consisted of three parts of corn chop to one part of tankage or 25% of tankage. This was done in order to give the ration about the same nutritive ratio and digestible constituents as white middlings. Aside from properly balancing the ration the larger quantity of tankage lessened the cost of the ration, as it costs $6 per ton less than the corn chop. This, however, is an unusual thing.

Samples of the feeds were taken to the experiment station laboratory at various times for analysis. Table I shows the composition of the feeds as fed, (the average of the different analyses being given.)

Table I.

	Moisture	Ash	Protein	Crude Fiber	N. Free Extract	Ether Extract
W. Middlings........	5.435	3.425	14.94	4.936	66.655	4.61
Corn Chop	5.656	1.805	9.375	2.19	77.164	4.40
Tankage.............	3.645	8.04	49.78	9.36	14.44	14.735

Table II shows the amount of dry matter and the amount of digestible nutrients in 100 pounds of feed fed.

Table II.

Digestible nutrients in 100 pounds of feed.

	Dry Matter	Protein	Carbohydrates	Ether Extract
W. Middlings	94.565	10.906	59.816	3.227
Corn Chop (corn meal)....	94.344	8.156	74.182	3.432
Tankage*	96.355	35.842	16.405	14.735

Using the figures as given in Table II the nutritive ratio or the ratio existing between the digestible protein and the digestible carbohydrates and digestible fat, of the white middlings is found to be 1:6.15 and that of the ration consisting of (corn meal three parts and tankage one part) is found to be 1 : 4.89. Thus it is seen that there appears a difference in the two rations so far as the digestible constituents are concerned. The standard ration for growing fattening hogs of three to five months of age calls for a nutritive ratio of 1 : 5 and hogs from five to six months of age 1 : 5.5. It will be noted that the ratios used in this experiment are one wider and the other narrower than the standard so far as the proportion of protein to carbohydrates and fat is concerned, and that they were made up of commonly used hog feeds, and fed under same conditions. The digestibility of tankage for swine was assumed to be the same as that of dried blood.

Table III gives the weekly weights of the pigs for the seventeen weeks through which the test was carried.

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* Digestion coefficients for dried blood used.

Table III.

Weekly Weights of Pigs.

Date.	Lot I.	Lot II.
Nov. 17	190.5	187.
Nov. 24	216.	194.5
Dec. 1	229.5	212.5
Dec. 8	259.5	236.5
Dec. 15	268.	252.
Dec. 22	294.5	280.5
Dec. 29	225.5	322.
Jan. 5	353.5	352.5
Jan. 12	359.5	359.
Jan. 19	373.5	380.
Jan. 26	401.5	413.
Feb. 2	423.	441.5
Feb. 9	444.	486.2
Feb. 16	456.	505.
Feb. 23	479.	533.5
Mar. 2	491.	570.5
Mar. 9	508.5	599.
Mar. 16	528.	635.5

It will be seen that the little difference of 5½ pounds there was in the initial weights of the two lots, was in favor of Lot 1, yet at the close of the experiment there was a difference of 107.5 pounds in favor of Lot II or the corn and tankage fed lot.

Table IV gives the weekly gains made by each lot.

Table IV.

Weekly Gains.

Period	Week Ending	Lot I.	Lot II.
1	Nov. 24	26.5	7.
2	Dec. 1	13.6	18.
3	Dec. 8	30.	24.
4	Dec. 15	8.5	21.5
5	Dec. 22	26.5	22.5
6	Dec. 29	31.	41.5
7	Jan. 5	28.	30.5
8	Jan. 12	6.	6.5
9	Jan. 19	14.	21.
10	Jan. 26	28.	33.
11	Feb. 2	21.5	28.5
12	Feb. 9	21.	44.7
13	Feb. 16	12.	19.2
14	Feb. 23	23.	28.5
15	Mar. 2	12.	37.
16	Mar. 9	17.5	29.5
17	Mar. 16	19.5	36.5
Average Weekly Gain . . .		19.92	26.44

From this table it is seen that Lot I (those fed middlings) made the better gains for the first three or four weeks, but after that almost without exception Lot II made much better and more consistent gains. Lot I did not make as good gains during the latter part of the experiment as they did in the first part. It was just the opposite with Lot II however. The average weekly gains of Lot II was also 6.1 pounds greater than that of Lot I or nearly a pound a day.

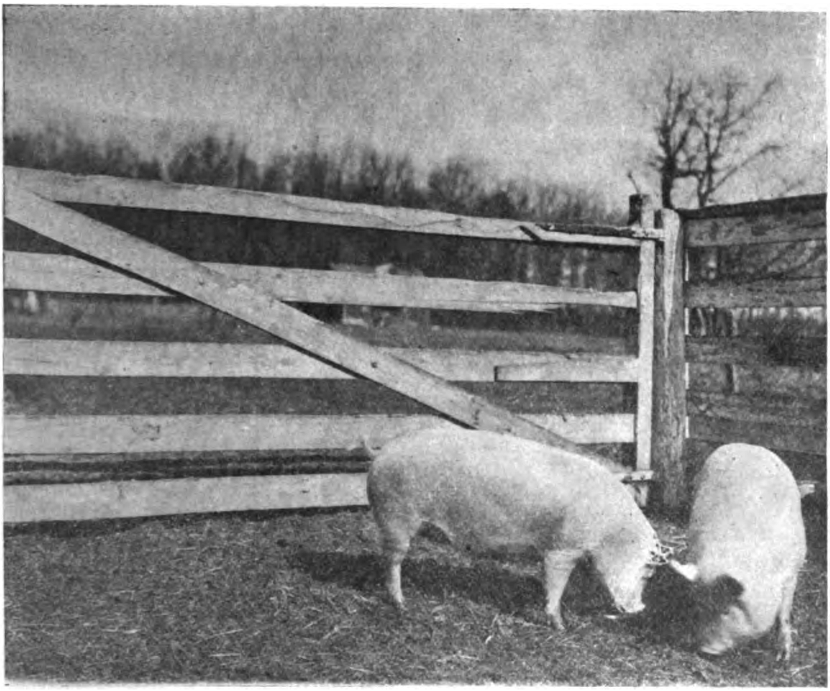
Table V gives the amount of feed consumed by each lot during each period.

Table V.

Feed Consumed.

Period	Lot I Middlings	Lot II. Tankage and Corn
1	61.	71.
2	73.	77.
3	79.	79.
4	84.	84.
5	84.	84.
6	90.	90.
7	96.	96.
8	103.	103.
9	106.	106.
10	112.	115.
11	112.	119.
12	118.	126.
13	98.	126.
14	98.	134.
15	98.	140.
16	98.	154.
17	105.	118.
	1615.	1822.

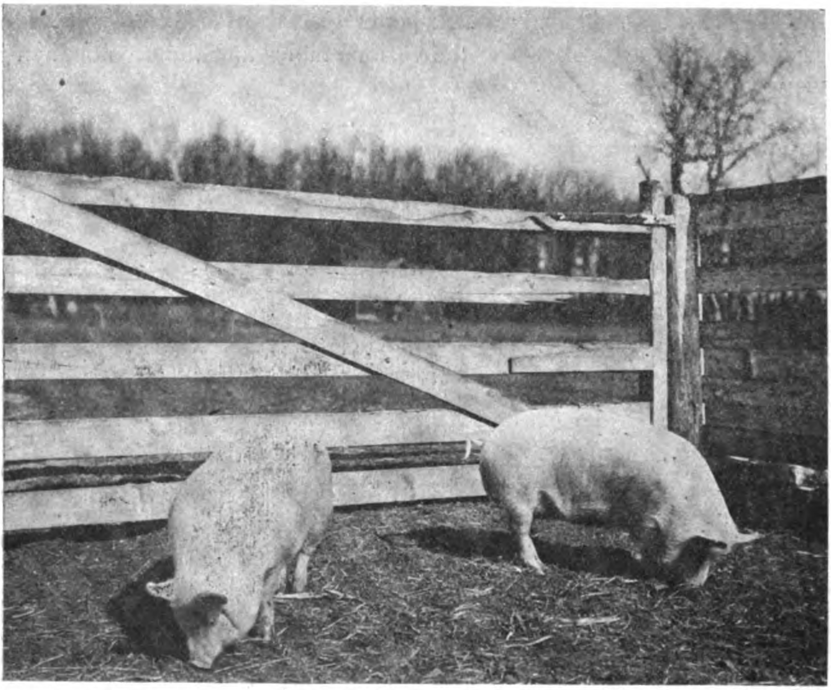
The above table indicates that Lot I did not take to the feed quite as readily as Lot II and it was not until the third period that Lot I consumed as much feed as Lot II. The amount of feed fed was regulated by the appetites of the pigs and increased or decreased accordingly. Lot I received the same amount of feed as Lot II until the tenth week when they seemed to reach a limit, and during the thirteenth week the feed was decreased, where it was kept for the remainder of the test. Lot II, however, demanded a gradual increase to the close of the experiment. At no time during the test did Lot I eat with the relish that did Lot II. Lot I was more paunchy than Lot II and never as bright and active. There was no especial difference in the skin and hair of the two lots. Lot II made much better growth of body in every way than did Lot I as is shown in the various tables and the accompanying views.



The Two Sows of Lot I

At about the middle of the experiment both lots became lame, Lot II slightly but Lot I badly, and they did not fully recover until near the close of the experiment. This trouble was probably due to close confinement on plank-floors, but from the fact that only one pig in Lot II was slightly affected, it would seem that the ration may have had some influence.

The following table, Table VI, is a statement of the cost of feed and value of the pork at the close of the test. It will be noted that no allowance is made in the statement for the original value of the pigs. The pigs were not sold live weight but the price per pound given below was fixed according to the market price at the time.



The Two Sows of Lot II

Table VI.

Financial Statement.

Lot I—1615 lb. Middlings	@ $30.00	per ton	=$24.23	
337.5 lb. Pork	@ .06¾	per lb.	= 22.78	
Loss				$1.45
Lot II—1404 lb. Corn Chop	@ $34.00	per ton	=$23.87	
468 lb. Tankage	@ 28.00	per ton	= 6.55	
Total cost feed			$30.42	
448.5 lb. Pork @ .06¾ pound			30.27	
Loss				$0.15
Difference in favor of II				$1.30

The table shows slightly less loss from the lot fed corn chop and tankage.

Table VII shows the individual weights of the pigs at the beginning and end of the experiment, the total gain per head, the average daily gain per head, the number pounds of food and dry matter per pound of gain and the cost per pound of gain for each lot.

Table VII.

Table showing total gain per head, average daily gain per head and cost per pound of gain.

		Weight per head at beginning of experiment	Weight per head at close of experiment (17 weeks)	Total gain per head	No of days fed	Average daily gain per head	No. of pounds feed per pound of gain	Cost per pound gain	Pounds of dry matter per pound gain
Lot I	Barrow No. 1..	65.5 lb.	187. lb.	121.5 lb.	119	1.021			
	Sow No. 2.....	63.	171.	108.	119	.908			
	Sow No. 3.....	62.	170.	108.	119	.908			
	Average.......	63.5	176.	112.5	119	.945	4.78	.072	4.57
Lot II	Barrow No. 4..	55.5 lb.	222. lb.	166.5 lb.	119	1.400			
	Sow No. 5.....	64.	198.5	134.5	119	1.130			
	Sow No. 6.....	67.5	215.	147.5	119	1.240			
	Average.......	62.3	211.8	149.5	119	1.257	4.06	.068	3.96

From this table it is seen that the barrows in each lot made much the better gains. The pigs of Lot II without exception made better gains and on the average on less feed and dry matter per pound of gain. The excessively high price paid for corn chop, however, brought up the cost per pound of gain in case of Lot II so that there was not much difference in the two lots in this respect. The ration fed Lot II was in this case slightly more economical than that fed Lot I, but with corn at an ordinary price there would be a greater difference in the cost of feeding the two rations in favor of the corn chop and tankage.

Slaughter Record.

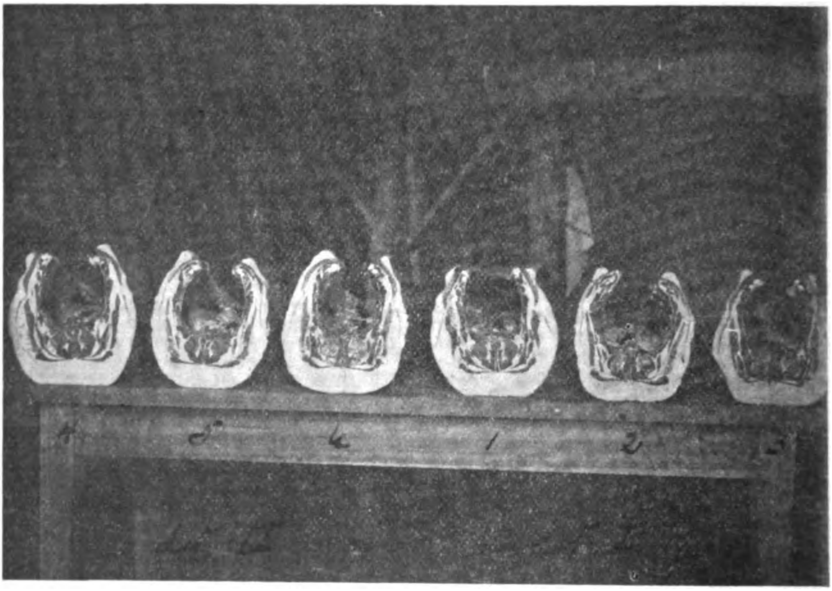
At the close of the test the animals were slaughtered in order to determine if possible the effects of the rations upon the carcasses of the two lots. The above tables are figured on a basis of seventeen weeks, but it was not convenient to kill at this time so the feeding was carried on the same as above for three days, when the barrows from each lot were killed. The sows were fed proportionately for three days longer, when they were killed.

Table VIII gives the weight previous to slaughtering (shrunk 24 hours) the dressed weight cold and the percent of dressed carcass to live weight.

Table VIII.

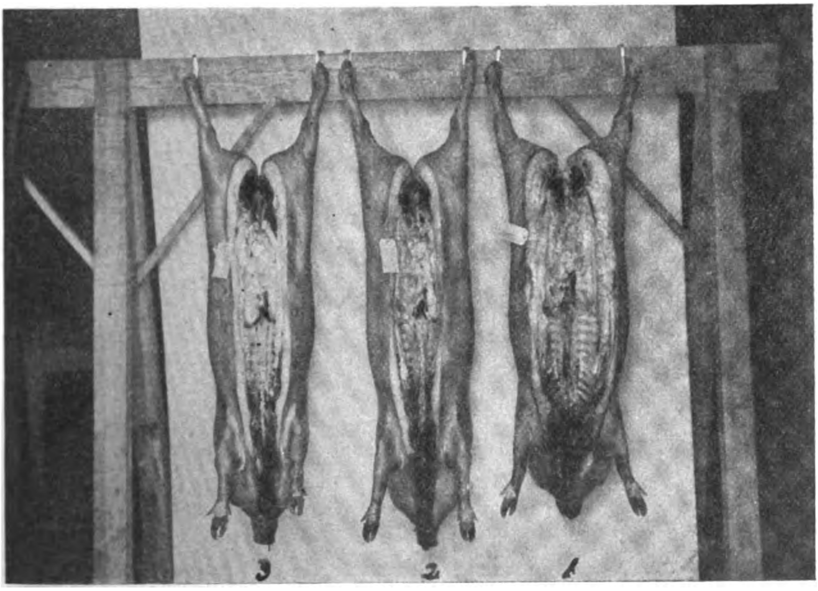
		Live Weight at beginning of experim't	Weight at slaughter shrunk 24 hours	Dressed Weight cold	Per cent. dressed weight carcass to live weight
Lot I	Barrow...No. 1	65.5	167	131.5	78.7
	Sow......No. 2	63	184	145	78.8
	Sow. ....No. 3	62	174	135.5	77.8
Average...........		63.5	175	137 3	78.4
Lot II	Barrow...No. 4	55.5	221	180	81.4
	Sow......No. 5	64	205	167	81.5
	Sow. ....No. 6	67.5	224	185.5	82.8
Average...........		62.3	216.7	177.5	81.9

It is interesting to note the difference in per cent. of dressed carcass to live weight of hogs as shown in the above table. There was a very noticeable difference in case of each individual in favor of the corn chop and tankage fed lot. The pigs of Lot II were more fully developed in every respect, at the same time they were not as paunchy as those of Lot I. There was practically no difference in the weight of the internal organs of the two lots, yet Lot II averaged 41.6 pounds the heavier on foot.



View of Carcass at Fifth Rib

The dressed carcasses did not show the differences that were expected. The relative proportion of fat and lean in the two lots was not noticeably different, neither was there any noticeable difference in the firmness and fibre of the lean meat. The fat, however, appeared firmer and of a little better quality in case of Lot II. The lean and fat in both lots were well intermingled or streaked and the lean carried well down in the sides, thus giving a very desirable piece for bacon.



Dressed Carcass of Lot I

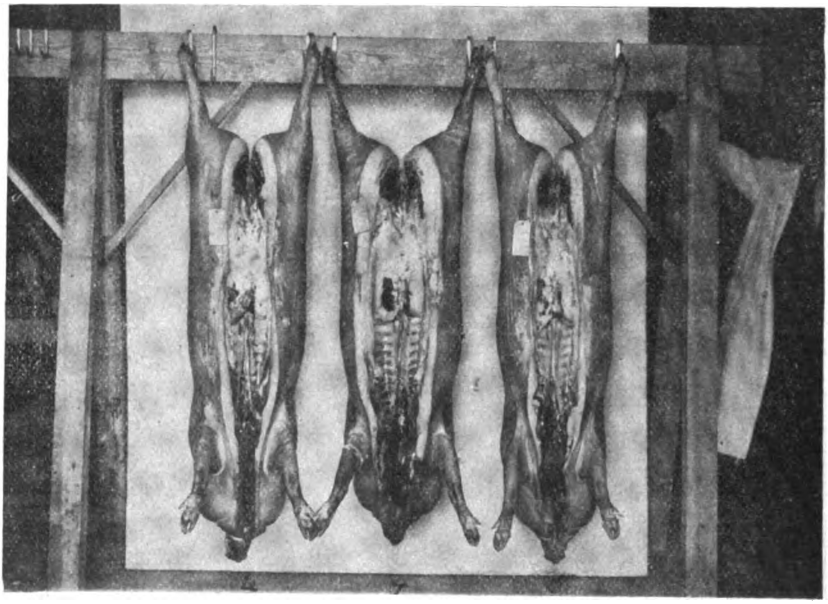
Samples of fat from each lot were taken to the Experiment Station laboratory for determination of melting point and per cent. of olein. Composite samples of both back fat and kidney fat were taken from each lot for analyses with the results shown in the following Table IX.

Table IX.

Melting Point	Back Fat		Kidney Fat	
	Lot I	Lot II	Lot I	Lot II
(Deg. Cent)	39.5	39.15	41.4	41.75
Iod. Hubl. No..............	57.97	59.85	60.82	55.22

Determination by G. C. Given. Department of Experimental Agricultural Chemistry.
Reported June 25, 1909.

These figures show practically no difference in the condition of the fat in the two lots. In fact it is not the difference that might have been expected.



Dressed Carcass of Lot II

While this test is decisive in some respects, the number of pigs was hardly enough for the best results. The results bear out the value of tankage for pigs when fed with corn as has been found at other Experiment Stations prior to this. The hogs like it and it is doubtful if any other of our concentrated feed stuffs will supply the protein to our hog ration so well as tankage.

Middlings are without doubt an excellent feed for young pigs previous to weaning and perhaps for a short time after, but beyond that they should make up only a small part of the ration for the growing and fattening hog.

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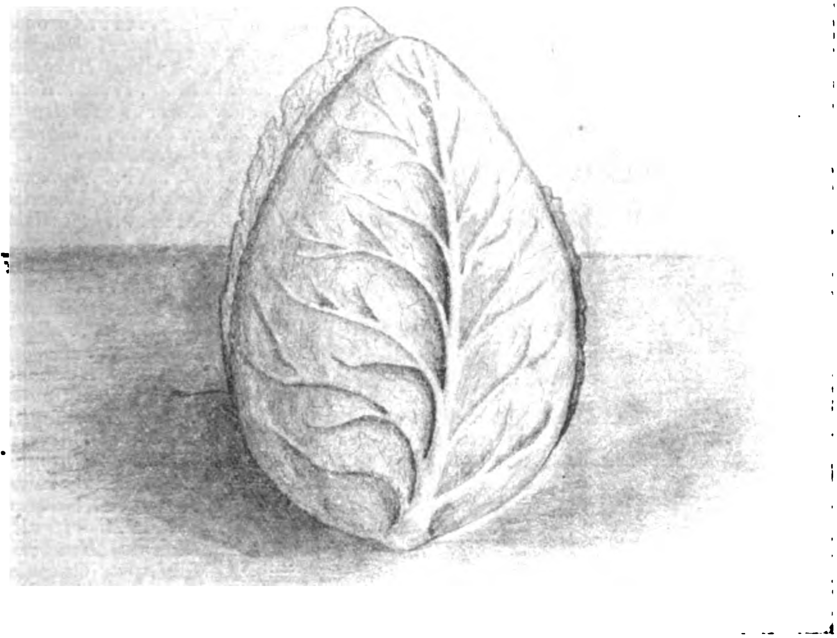

A STRAIN TEST OF JERSEY WAKEFIELD CABBAGE

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 96

A STRAIN TEST OF JERSEY WAKEFIELD CABBAGE

By C. E. MYERS

SUMMARY.

1. The experiments with twenty-five strains of Jersey Wakefield cabbage, covering a period of two years, indicate that marked variations occur within the variety.

2. These variations have a direct bearing upon profitable crop production. There are great differences in earliness, yields, form and solidity of heads, and each of these factors is important in determining profits for the season.

3. The degree of vigor of the young plants in the seed bed is of no value in indicating the size or character of the resultant crop.

4. The percentage of germination of some strains was much too low, and it is important for seedsmen to give this matter closer attention.

5. The wide variations and lack of uniformity in this variety show the importance of exercising the utmost care and skill in producing and selecting cabbage seed.

6. For a brief summary of the tests consult table on page 10.

7. While the results of the two years' test show wide variations in strains of Jersey Wakefield cabbage, the investigations will be continued several years to determine more definitely the full importance and significance of such differences.

Wheat Production.

A study of the wheat statistics of Pennsylvania for the past four decades, shows that the acreage during that period has never fallen below the million mark, and the minimum annual value exceeds eleven millions of dollars. In 1908 the wheat crop from 1,590,000 acres was valued on December 1st, at $29,121,000. A greater value was never before placed on this crop in Pennsylvania. The year 1909, just closed, shows a slight reduction in both acreage and value over the preceding one, the acreage being 1,545,000 and the estimated value $28,629,000. The following table gives the average annual acreage, production and value by decades:

Table I.

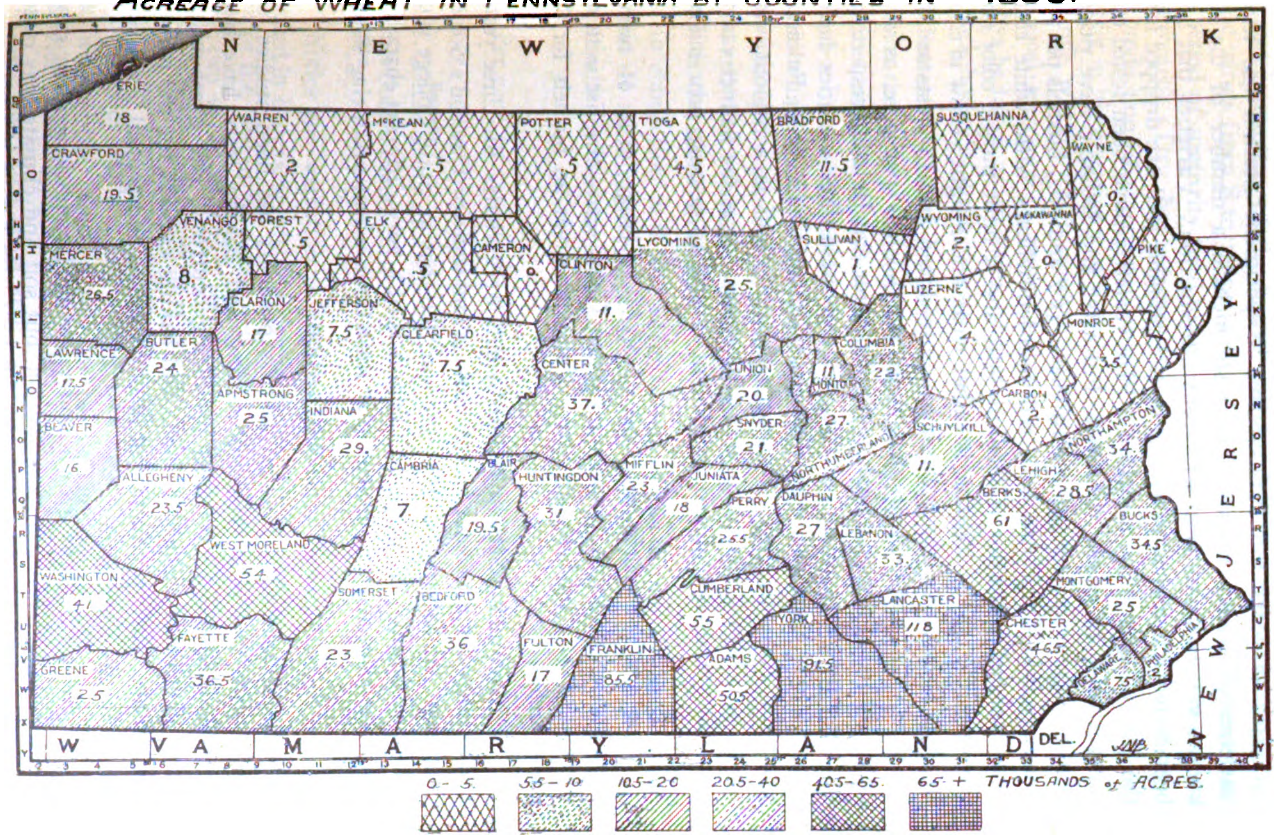
Acreage, Production and Value of Wheat in Pennsylvania for 40 years. Average by 10 year periods.

Period	Acres	Production by Bushels	Value
1869-78	1,242.358	17,097,600	$20,228,683
1879-88	1,460,660	18,855,028	19,883.430
1889-98	1,337.161	20,312,447	16,084,866
1899-1908	1,594,167	25,838,349	21,525,240
Average for 40 years	1,408,586	20,525,856	$19,430,555

These statistics show an increase of 352,000 acres for the decade ending in 1908 over that for the ten years ending 1878, with a comparatively small increase in value for the same periods. Eighty cent wheat is a thing of the past and the coming decade will show a marked average increase in the annual value of our wheat crop.

The accompanying map shows the acreage of wheat in Pennsylvania by counties, census of 1899. It will be seen that Lancaster is the banner county with 118,000 acres, York and Franklin are close seconds with 91,500 and 85,500 acres respectively. There are only six counties of the second class, producing from 40 to 65 thousand acres, viz: Chester, Cumberland, Adams, Berks, Washington and Westmoreland, while there are 23 counties in the central and southern part of the state that produce from 20 to 40 thousand acres each, and a lesser number in the central and northern section that produce from 10 to 20 thousand acres. Of the two northernmost tiers of counties only five have an acreage exceeding ten thousand. Is it not evident that the industry is of sufficient magnitude to justify a study of the milling and baking qualities of our wheats with a view to improvement?

ACREAGE OF WHEAT IN PENNSYLVANIA BY COUNTIES IN 1899.



Variety Tests.

For 19 years the Pennsylvania Experiment Station has tested varieties of winter wheat. The tests include a number of the best known varieties and those of recent introduction. Varieties that have been tested for several years and do not promise well are dropped from the list and give place to others. Five varieties have been tested continuously for 19 years. Of these, Fulcaster and Reliable have yielded best, giving, as an average for 19 years, 31.7 and 30.9 bushels per acre respectively. These are both red bearded wheats with white chaff. The straw of Fulcaster is medium stiff and a light purple color near the top while that of Reliable is rather weak and a light yellow in color. In 1897 Dawson's Golden Chaff was introduced into the tests and the average yield for 12 years has been 31.4 bushels per acre, as compared with 30.2 and 29.9 bushels for Fulcaster and Reliable respectively for the same years. The average yield for these three varieties during the past four years has been: Dawson's Golden Chaff, 36.4; Fulcaster, 33.8; and Reliable, 32.6. Dawson's Golden Chaff is a smooth white wheat with brown chaff and very stiff straw. It is the banner variety from the standpoint of production but is said to possess poor milling qualities.

The Ohio Experiment Station reports average yield of twelve years for 27 varieties. Dawson's Golden Chaff leads the list with an average of 31.4 bushels per acre. Fulcaster gives 29 bushels for the same period.

The Kentucky Station reports yields of varieties for three years. The average for Fulcaster is 29.6 bushels and that for Dawson's Golden Chaff 25. At Lexington, Ky., the soil like that at State College is of limestone origin. At Wooster, Ohio, it is of a very different character. These varieties are well known in at least three wheat producing states.

Composition.

The composition of wheat and its products has been studied for many years and more recently milling and baking tests have been undertaken in the large wheat producing centres. The great millers of the Northwest employ chemists and baking experts for the purpose of improving their products, but in our Eastern and central states such tests have not been made.

Varieties of wheat grown under identical conditions often show considerable difference in composition, but soil and climate may cause greater variation in a variety than will be found between different varieties grown side by side. Such variation is especially marked with the protein content of the kernel and we find that this constituent in wheat varies from 8 to 18 per cent. Conditions favorable to growth at the period of maturity tend to develop starch and result in a low protein content. Dry, hot weather at this period hastens maturity, checks the production of starch and results in a higher percentage of protein. Snyder in his chemistry of plant and animal life, states that "As a general rule, wheats which contain the largest amount of nitrogen produce the most nitrogenous flours, but the total nitrogen in wheat cannot always be taken as an index of that in the flour." Exceptions are due to thick layers of bran, aleurone and large germs.

Protein is one of the most valuable constituents of food. Wheat contains the largest amount of proteids of any of the cereals. It is used as human food more extensively than any other cereal. With the exception of rye, wheat is the only grain which contains gliadin, the proteid which forms dough and with the gas causes expansion of the mass during the process of bread making. A study of the proteids of wheat and their relation to the quality of flour for bread and other purposes, is therefore valuable.

In connection with the variety tests at the Kentucky Station the protein of each variety was determined for three consecutive years. The results for two varieties in which we are interested are as follows:

Table II.

Per cent. of protein in wheat grown at the Kentucky Station.

Variety	1905	1906	1907	Average
Dawson's Golden Chaff.....	12.13	13.37	12.87	12.79
Fulcaster............	14.40	18.06	14.63	15.70

Notice the variation in protein from year to year which is most marked in Fulcaster, showing an increase of 3.66 per cent. in 1906 over that of the preceding year, or a difference greater than the average of these two varieties which represent the high and low protein types of the 27 varieties analyzed. It is interesting to note that the milling qualities of these wheats were also rated by Mr. W. W. Patterson of the Lexington Roller Mills. The rating was apparently made by inspection and was on the basis of 100 for perfect milling wheat. Of the 31 varieties rated in 1905 the highest rating was 95 and the lowest 80. Fulcaster was rated at 94 and Dawson's Golden Chaff at 85. In 1906 the rating of the same 31 varieties shows a range from 98 to 85. Fulcaster was rated at 98 and Dawson's Golden Chaff at 87. We have the protein content of these two wheats as grown in Kentucky showing differences that indicate one to be superior to the other, and we also have the judgment of an expert miller rating one high in milling qualities and the other very low.

Dawson's Golden Chaff and Reliable as grown on the college farm at State College, Pa., and Fulcaster as grown near Lock Haven, Pa., all in 1908, have a protein content, (water-free basis) of 9.90, 10.12 and 12.15 per cent. respectively. While this protein content is much lower than that obtained in Kentucky the relative amounts in Dawson's Golden Chaff and Fulcaster are of the same order. The protein content of these wheats indicate that Fulcaster would produce a more nutritious and better bread making flour than Dawson's Golden Chaff, and an experienced miller has rated the former much above the latter in milling qualities. But what are the facts in the case? Which wheat will require the lesser number of bushels to mill a barrel of flour? Which flour will make the most nutritious, palatable and attractive loaf, and which the largest number of loaves to the barrel of flour? Most of us are like the man from Missouri. We need to be shown.

Milling Test.

The officers and board of directors of The Pennsylvania Millers' State Association in co-operation with the Pennsylvania Experiment Station arranged a milling test which was made in Bellefonte last May. The milling was done in a thoroughly satisfactory manner in the up-to-date mill of Messrs. Gamble and Gheen under the supervision of Mr. Gamble. The variety Fulcaster was secured by the milling firm from a grower near Lock Haven, while the other two varieties were supplied by the Experiment Station and were grown on the College farm. Samples and weights were taken by officers of the Experiment Station in the presence of representatives of The Millers' State Association. Samples of the wheat, the flour and the by-products of each variety have been analyzed and the results given on a subsequent page. For the varieties Dawson's Golden Chaff and Fulcaster three runs of 50 bushels each were made. There was only 50 bushels of Reliable which admitted of only one run. Weights and samples were taken of each of the seven runs. The following table gives the pounds of the several products produced by 100 pounds of uncleaned wheat, that of Reliable being for a single run and that for the other two being an average of three runs.

Table III.

Products from 100 pounds of uncleaned wheat, lbs.

Variety	Screenings	Scourings	Bran	Shorts	Flour	Loss	Total
Dawson's Golden Chaff, average 3 runs,	.99	.44	17.02	11.50	69.60	.45	100
Reliable, 1 run	.20	.32	15.50	12.65	70.31	1.02	100
Fulcaster, av. 3 runs	.22	.29	17.09	11.50	69.83	1.07	100

It took four bushels and thirty-nine pounds of Dawson's Golden Chaff to make a barrel of flour, while for Reliable and Fulcaster it took four bushels and thirty-six pounds and four bushels and thirty-eight pounds respectively. Variations between runs of the same variety were greater than between averages of two varieties. So far as this test is concerned there is practically no difference in the yield of flour.

Four bushel lots of each variety were also sent to the Grain Standardization Laboratory of the U. S. Department of Agriculture located at the North Dakota Agricultural College. There, as in case of the 50 bushel tests, a straight flour was made from two bushel samples. An equal amount was used to determine how much patent flour would be produced by each variety. The following table gives the product from 100 pounds of wheat for both the straight and patent flour tests.

Table IV.

Products from 100 pounds of cleaned wheat, lbs.

Variety	Bran	Shorts	Flour	Loss	Total
Dawson's Golden Chaff—					
Straight	15.10	16.66	63.46	4.78	100
Patent	12.83	17.09	62.82	7.26	100
Reliable—					
Straight	16.34	17.19	60.87	5.60	100
Patent	16.30	16.20	62.48	5.02	100
Fulcaster					
Straight	14.17	18.68	61.80	5.35	100
Patent	14.18	16.69	65.16	3.97	100

A comparison of this test with that made on the 50 bushel lots shows a considerably lower yield of flour and a much greater loss in milling. The combined amounts of bran and shorts are also appreciably greater in this test. For a straight flour, it required in this laboratory test, five bushels and nine pounds of Dawson's Golden Chaff, for a barrel of flour and five bushels and seventeen pounds of Fulcaster to make a like amount of flour. When the patent flours were made the order was reversed and it required five bushels and one pound of Fulcaster and five bushels and twelve pounds of Dawson's Golden Chaff per barrel. The average is five bushels and ten pounds for Dawson's Golden Chaff, five bushels and fifteen pounds for Reliable and five bushels and eight pounds for Fulcaster.

It is evident from these tests that the method of milling has more influence on the yield of flour than the varieties tested. In the patent flour test the percentages of the three grades of flour for the varieties tested are given in the following table.

Table V.

Classes of Flour, per cent.

Variety	Patent	First Clear	Second Clear	Total
Dawson's Golden Chaff.....	72.80	22.78	4.42	100
Reliable...................	71.10	26.30	2.60	100
Fulcaster	76.00	20.00	4.00	100

Here, as in case of the straight flour, the differences are slight, the maximum per cent. of patent being secured from Fulcaster. This is a very satisfactory proportion of patent flour and exceeds by several per cent. the average yield of fifteen varieties of Northwestern spring wheats as milled at the same place and reported in Bulletin No. 82, of the North Dakota Experiment Station.

From these tests and for these varieties it seems evident that the important consideration is not in the yield of flour. If differences in the value of these varieties exist we must look for them in the composition or the quality of the flour.

Under the able direction of our chemist, Dr. William Frear, a complete analysis has been made not only of the wheat and flour but of all the products of the milling test. A determination of the gluten was also made together with the various constituents of which it is composed. The following tables give the percentage composition of the several products of the three varieties of wheat. The percentage of moisture is so nearly the same for the three wheats and the several products resulting that comparisons will bear essentially the same relation as when calculated to a water-free basis.

Table VI.

Composition of scoured wheat and flour.

	SCOURED WHEAT			FLOUR		
	Dawson's Golden Chaff	Reliable	Fulcaster	Dawson's Golden Chaff	Reliable	Fulcaster
Moisture	13.18	13.01	13.26	12.84	12.56	13.18
Ash	1.94	1.89	1.99	.44	.48	.53
Protein	8.60	8.80	10.54	7.55	7.54	8.83
Fiber	2.28	2.25	2.31	.27	.26	.26
Nit. free ext	71.95	72.35	70.12	78.11	78.24	76.40
Crude fat	2.05	1.70	1.78	.79	.92	.80
	100 00	100.00	100.00	100.00	100.00	100.00

In Table VI there are no differences in constituents, other than the protein worthy of more than a glance. We have already seen that the wheat of the variety Fulcaster both here and in Kentucky is richer in protein than that of Dawson's Golden Chaff. As is always the case, the flour contains less protein than the wheat from which it is made. The relative amounts in the three flours are essentially the same as in the wheats. The fat in the wheat of Dawson's Golden Chaff is appreciably higher than in the others, but it evidently lost in the by-products for the flour is no better in this respect than that from Fulcaster.

The composition of the bran and shorts, which are by-products, is of less importance than that of the grain and flour, but since the two products are so highly prized for dairy cows a passing glance at their composition is permissible.

Table VII.

Composition of Bran and Shorts.

	BRAN			SHORTS		
	Dawson's Golden Chaff	Reliable	Fulcaster	Dawson's Golden Chaff	Reliable	Fulcaster
Moisture	11.92	12.29	12.11	12.36	12.59	12.64
Ash	6.11	5.86	6.45	3.31	3.90	3.69
Protein	12.11	12.16	13.28	12.22	12.82	13.59
Fiber	8.37	8.27	8.68	3.73	5.00	4.72
Nit. free ext	56.53	57.03	55.27	63.28	61.59	60.88
Crude fat	4.96	4.39	4.21	5.10	4.10	4.48
	100.00	100.00	100.00	100.00	100.00	100.00

In Table VII there are no striking differences in the composition of these products. Both bran and shorts are relatively rich in ash, protein and fat as compared with the whole wheat or the flour. The higher fat content of Dawson's Golden Chaff Wheat, none of which showed in the flour, is manifested in both of these products, being an average of three-fourths of one per cent. higher than for the other two varieties. The higher protein of the Fulcaster wheat and flour is also apparent in both the bran and shorts although the difference is less than in the grain.

Table VIII.

Composition of Screenings and Scourings.

	SCREENINGS			SCOURINGS		
	Dawson's Golden Chaff	Reliable	Fulcaster	Dawson's Golden Chaff	Reliable	Fulcaster
Moisture	13.16	12.06	12.84	10.15	10.41	11.29
Ash	2.29	2.96	2.65	3.52	3.41	3.39
Protein	9.12	10.65	10.60	11.74	11.77	11.59
Fiber	3.65	4.80	4.03	14.65	16.85	15.37
Nit. free ext.	69.60	67.22	67.62	56.29	54.31	55.21
Crude fat	2.18	2.31	2.26	3.65	3.25	3.15
	100.00	100.00	100.00	100.00	100.00	100.00

The composition of the screenings and scourings given in Table VIII are of little economic importance because these products form so small a part of the total. In this test these combined products aggregated percentages as follows: Dawson's Golden Chaff, 1.43; Reliable, .52; and Fulcaster, .51. The screenings, composed of broken kernels, some foreign seed, nodes of straw and light material does not differ materially in composition from the wheat from which it was separated, although it runs a little higher in ash, protein, fibre and fat. Its composition is more uniform for the three wheats than one would expect. The scourings, which one would suppose to consist of the hairs and external particles of the bran, together with adhering dust and dirt, has a composition similar to the bran but is appreciably lower in ash and fat, slightly lower in protein and very much higher in fiber. The differences in the composition of these products for the three varieties of wheat are not worthy of mention. The results as recorded may be useful for future references and further consideration of them omitted for the present.

Proteids as Related to Quality.

The proteids of wheat are albumin, globulin, proteose, gliadin and glutenin. The last two are insoluble in water and together form gluten, a tough, elastic, spongy material that may be determined in a rough way by mixing a weighed portion of flour with water into a stiff dough and, after the dough has stood for a little time, washing it under a gentle stream of water until it is free from starch. Gluten is usually weighed first in the wet and afterward in a thoroughly dry state. Its physical qualities as well as the quantity are indicative of the baking quality of the flour. According to Snyder the gluten of good wheat constitutes from 80 to 85 per cent. of the total proteids and consists of 60 to 65 per cent of gliadin and 35 to 40 per cent. of glutenin. Gliadin may be separated from either gluten or flour with a 70 or 75 per cent. solution of alcohol and is obtained by evaporating to dryness. Gliadin is the material which binds together the flour to form dough and enables the mass to expand, retaining the gas generated by the yeast, or liberated from baking powder.

Glutenin is the proteid which remains after gliadin is extracted from gluten. It also plays an important part in bread making. Glutenin combines mechanically with gliadin and, serving as a nucleus to which the latter adheres, prevents the dough becoming too soft and sticky. Glutens of high quality are usually hard, elastic and of a light yellowish color.

The per cent. of wet and dry gluten in these wheats as determined under the direction of Dr. Frear are given in Table IX. There is also given the average of four determinations as made in practicum work by students in agricultural chemistry. It should be borne in mind that this determination is subject to error and requires much practice to get consistent results. If the washing is too rapid some of the gluten will be carried away and the result will be too low. If not washed long enough some starch will remain and the result be too high.

Table IX.

Gluten contents of flour, per cent.

	Station Determination			Students' Determination		
	Dawson's Golden Chaff	Reliable	Fulcaster	Dawson's Golden Chaff	Reliable	Fulcaster
Moist Gluten	17.59	16.33	23.90	19.10	17.91	24.35
Dry Gluten	6.21	5.59	8.06	7.50	7.55	8.84
Glutenin	2.05	2.04	1.88			
Gliadin	4.55	4.62	5.98			
Per cent. of protein as gluten	82.2	74.4	91.3			
Per cent. of protein as gliadin	60.3	61.3	67.7			

In both sets of the above determinations, Fulcaster shows an appreciably higher gluten content than the other two wheats. This is consistent with the protein content as given for both wheat and flour. In case of the student's determinations, the relative amounts run well but all are apparently a little too high. The glutenin and gliadin determinations were made by the provisional method of the Association of Official Agricultural Chemists. In each of the varieties the ratio of gliadin to total protein is exceptionally high and especially is this so in case of Fulcaster. This ratio exceeds that obtained for many varieties of Northwestern wheats as determined at the North Dakota Experiment Station and reported in Bulletin No. 82.

Baking Tests.

Under the direction of Mr. L. A. Fitz, in charge of the Fargo Laboratory of Grain Standardization, for the United States Department of Agriculture, baking tests were conducted in conjunction with the milling tests. Bread was made from the straight flour and from each of the three grades of flour for each variety of wheat. The following tables give the results of the baking tests, 340 grams of flour being used for each loaf baked.

Table X.

Baking tests with straight flour.

	Dawson's Golden Chaff	Reliable	Fulcaster
Water used, grams	163	164	164
Weight of loaf, grams	468	471	471
Volume of loaf, c. c.	2080	2065	2250
Color	1	1	1
Texture	Good	Good	Very Good
Dough	Very short and brittle	Rather short	Somewhat elastic
Crumb	Good Color	Very white	Creamy White

Table XI.

Baking tests with patent flour.

	Dawson's Golden Chaff	Reliable	Fulcaster
Water used, grams	160	160	165
Weight of loaf, grams	463	463	470
Volume of loaf, c. c.	2125	2060	2230
Color	1	1	1
Texture	Very good	Good	Good
Dough	Short	Short	Somewhat elastic
Crumb	Good color	Good Color	Dead White

Table XII.

Baking Tests with first clear flour.

	Dawson's Golden Chaff	Reliable	Fulcaster
Water used, grams	163	168	168
Weight of loaf, grams	471	479	470
Volume of loaf, c. c.	2060	2040	2180
Color	1	1	1
Texture	Excellent	Very Good	Good
Dough	Short	Short	Rather Short
Crumb	Good Color	Trifle dull	Dull

Table XIII.

Baking tests with second clear flour.

	Dawson's Golden Chaff	Reliable	Fulcaster
Water used, grams	173	176	170
Weight of loaf, grams	484	485	471
Volume of loaf, c. c.	2040	1910	2250
Color	1	1.5	1.5
Texture	Very Good	Good	Good
Dough	Short	Short	Rather Short
Crumb	Little Creamy	Little dull	Trifle Gray

An examination of Tables X to XIII inclusive brings out the following points in regard to the character of loaf or dough for the three varieties of wheat. For the straight flour the dough of Dawson's Golden Chaff was very short and brittle; that for Reliable rather short and for Fulcaster somewhat elastic. With the patent flour the dough of both Dawson's Golden Chaff and Reliable was recorded as short, while for Fulcaster it was somewhat elastic. For both the first and the second clear flour the dough from Dawson's Golden Chaff and Reliable was short and that from Fulcaster rather short. On an average the flour from Fulcaster was capable of taking a little more water than that from Dawson's Golden Chaff and made a loaf weighing slightly more. On an average the volume of loaf from Fulcaster exceeded that from Dawson's Golden Chaff by 7.3 per cent. and exceeded that of Reliable by 10.3 per cent. Further than this there is nothing to indicate superiority of one over another.

Of the straight flour secured from the 50 bushel tests, samples were sent to the Domestic Science School at State College and one loaf was made from each of the three flours on two occasions. The report received states that in each trial Fulcaster gave best results as to consistency, taste and texture. It also kept better. On August 11th another baking test was made at the Harvey Brothers Bakery, State College. The flour of Dawson's Golden Chaff and Fulcaster only was used in this test. Sixteen pounds of flour was used in each case and made 24 pound loaves. The bread of each variety was sent to various persons and boarding houses in State College with requests that reports on the quality be furnished. The reports generally stated that both breads were of good flavor and aroma. Where there was a difference on this point it was in favor of Fulcaster. Fulcaster was reported generally as being a little the lighter and of better texture.

The writer's observations on the test may be summed up in these words. The Fulcaster dough was quite elastic, that from Dawson's Golden Chaff was very short and easily broken. The Fulcaster dough was not so elastic as that from flour said to be from Northwestern spring wheat that was being baked for the trade. When baked, the Fulcaster loaves were largest and were reasonably light. The texture and color of both crumb and crust were good. The Golden Chaff loaves were slightly smaller and less spongy. The texture was slightly coarse and the color of the crumb had a faint yellow tinge. The crust on some of the loaves was scarred where it had broken in the process of baking. Twenty loaves of Fulcaster weighed 18 pounds and 5 ounces. The same number of loaves of Dawson's Golden Chaff weighed 18 pounds and 4 ounces.

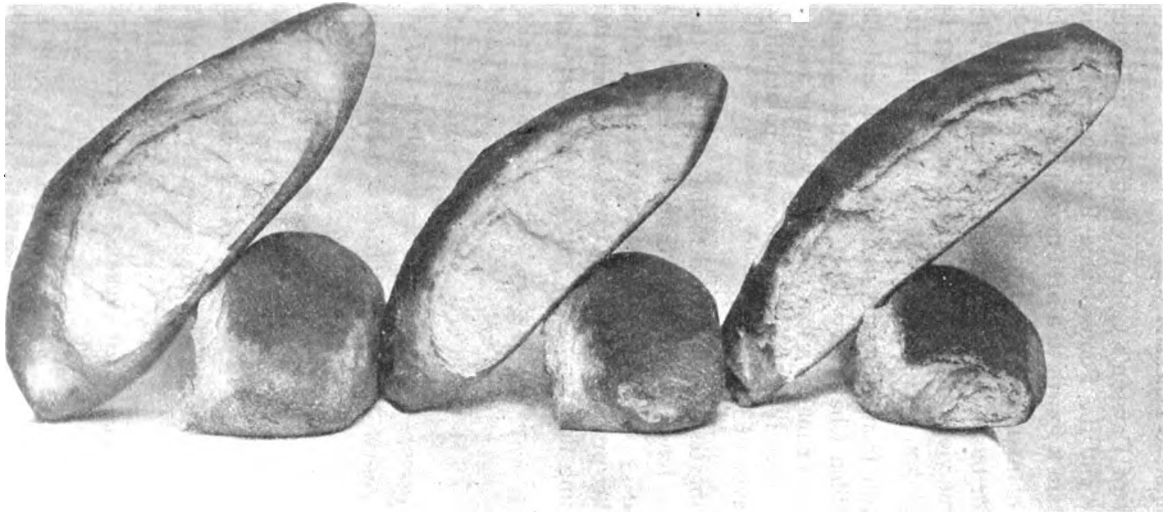
The accompanying photograph shows two representative loaves from each variety compared with two loaves made from Northwestern spring wheat.

Summary.

Dawson's Golden Chaff is a soft, white, beardless winter wheat with stiff straw. As a result of trial for twelve consecutive years, at both the Ohio and Pennsylvania Experiment Stations, it has out-yielded all other varieties tested.

Fulcaster is a red, bearded, winter wheat with medium stiff straw and the grain is much harder than Dawson's Golden Chaff. It is a standard variety and holds a high rank for yields at both the Ohio and Pennsylvania Experiment Stations. In tests for three years at the Kentucky Experiment Station, Fulcaster out-yielded Dawson's Golden Chaff.

BAKERS' BREAD FROM THREE VARIETIES OF WHEAT



1—Minnesota Spring Wheat; weight of two loaves, 26.5 oz. 2—Red Winter Wheat, variety Fulcaster; weight of two loaves, 29 oz. 3—White Winter Wheat, variety Dawson's Golden Chaff; weight of two loaves, 28.5 oz.

Reliable, like Fulcaster, is red bearded winter wheat. Its straw is rather weak. At the Pennsylvania Experiment Station its yield has been nearly equal to Fulcaster.

Analyses of Dawson's Golden Chaff and Fulcaster as reported at the Kentucky and the Pennsylvania Experiment Stations, shows Fulcaster to contain a fourth to a fifth more protein than Dawson's Golden Chaff.

Bushel for bushel Dawson's Golden Chaff and Fulcaster give practically the same yield of flour. The flour of Fulcaster is highest in both protein and gluten. Its gluten is also relatively high in gliadin.

The dough from Fulcaster is fairly tough and elastic; that from Dawson's Golden Chaff very short and brittle. From equal amounts of flour, Fulcaster makes a loaf of larger volume and one that is lighter and of better texture. In appearance and palatability the consumers reported in favor of Fulcaster.

The baking tests were limited to the quality of the flour for bread only and may have shown quite different results if extended to the making of pastry, crackers and other products. We need to study the making of other products as well as bread in order to determine the best manner of using flour from our soft winter wheats.

THE PENNSYLVANIA STATE COLLEGE AGRICULTURAL EXPERIMENT STATION

LIST OF PUBLICATIONS AVAILABLE

The following publications of the Experiment Station are now available and will be mailed free on application:

Reports 1897, 1898-9, 1899-1900, 1900-1, 1901-2, 1902-3, 1903-4, 1905-6, 1906-7.

Bulletin 38. Test of Hand Separators.
" 46. Variety Tests of Wheat.
" 49. Field Fertilizer Experiments on Tobacco.
" 50. Distillery Waste: Miscellaneous Cattle Food Analysis.
" 52. Rye Meal and Quaker Oats Feed for Milk Production.
" 59. Pennsylvania Sugar Beets in 1901.
" 61. Report of the Director.
" 68. Methods of Steer Feeding.
" 71. Relative Values of Feeding Stuffs.
" 72. Experiments in Growing Sumatra Tobacco Under Shelter Tent, 1903.
" 77. Small Fruits.
" 78. A Test of Commercial Cultures for Legumes.
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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 98

POTATO VARIETY PLATS. 1909

A VARIETY TEST OF POTATOES

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
MARCH, 1910

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The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 99

PREPARATION AND USE OF CONCENTRATED LIME-SULPHUR

JOHN P. STEWART

The art of spraying is now in a state of transition. This transition involves the breaking away from Bordeaux mixture and the whole list of copper sprays which have served as fungicides for more than a quarter of a century and the substitution of what may become an equal list of sulphur sprays. It also involves the abandonment of old formulas and processes for making the latter sprays and the substitution of more definite, economical and less disagreeable methods. Just how complete the transition will be can hardly be predicted. But this is certain that, whereas two years ago we might readily have told how best to spray a tree, today we must wait for further results before this can be finally stated.

Among these coming sprays, the clear concentrated lime-sulphur solution will undoubtedly occupy a leading place. In the commercial form this solution already has a satisfactory insecticidal record of some seven or eight years. In the new concentrated home-preparation, it has an excellent record both as an insecticide and fungicide, being first used by Cordley of the Oregon Station in 1907.[1] Realizing the importance of this work, in the latter part of 1908, the writer undertook to determine the essential features of the preparation of a storable lime-sulphur solution and if possible, to render its use available to orchardists.[1]

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[1] An account of his method of preparation appeared in "Better Fruit" in April, 1909.

In brief, the results of this study are as follows. In the making of a storable lime-sulphur at home, we must first get the formula right. This is accomplished by using one pound of good lime[2], two pounds of sulphur, and one gallon or a little more of water, boiling it all down so as to have about one gallon of total product at the close.

In some cases this formula may well be modified slightly. For example, if the lime falls much below 95% calcium oxide or if the solution is to be used at once, it may be desirable to increase the amount of lime by as much as 10%, thus making the formula 1.1-2-1. But any appreciably greater increase in the lime is objectionable because of resulting increases in the amount of sediment, in the tendency to crystallize in storage, and in the formation of only the lower sulfids. Under most conditions, therefore, the 1-2-1 formula should be followed, with the understanding that slight increases in the relative lime content are permissible where conditions warrant.

The kind of sulphur may be either flour, flowers, or "powdered commercial" at least 99½% pure.[3] The kind last named is probably most desirable, with the flour next, on account of cheapness and the somewhat reduced tendency to form pellets in the process of mixing.

Utensils

The utensils needed are a cooker, measuring stick, strainer and hydrometer. A fine screen for sifting the sulphur may also be desirable. With a cooker using bottom heat, their total cost need not exceed $15 or $20.

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1. This publication slightly modifies and extends certain portions of our Bulletin 92, the supply of which is nearly exhausted. It deals only with the practical details needed by the orchardist. If the original data and reasons are desired, the reader is referred to the complete account in the Annual Report of this Station for 1908-9. Persons desiring this Report should apply to their State Senator or Representative.

2. Lump lime containing not less than 90 per cent. calcium oxide, and preferably 95 per cent. or more, with as little magnesia as possible, preferably not over 3 per cent. Such lime in car lots is obtainable from the American Lime & Stone Co., Tyrone, Pa., or from the York Valley Lime Co., or L. M. Palmer, York, Pa.

3. Any of these kinds may be obtained in quantity from the Bergenport Sulphur Works, or the Brooklyn Sulphur Works, New York City; or Powers-Weightman-Rosengarten, or the General Chemical Co., Philadelphia; at prices ranging from $1.65 to $2.60 per 100, depending on kind and quantity ordered.

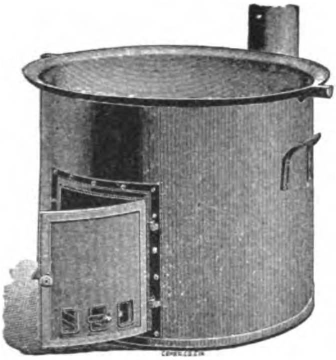

Figure 1

A convenient cooker for use in making concentrated lime-sulphur. Obtainable from Montgomery Ward & Co., Chicago, Ill.: The Wagner Mfg. Co., Sydney, Ohio: or the Farmers Supply Co., Philadelphia, Pa., and the largest sizes are preferable if much material is to be made.

The Cooker.—The cooking may be done either in an ordinary iron kettle with a fire beneath, or by means of steam in vessels of iron or wood. A cooker found very satisfactory in our work is shown in Figure 1. It is valuable because of its economy of fuel and the ready control of the fire it affords by means of the door and damper. It is especially useful where moderate amounts of material are required, or where the cooking may chiefly be done in advance.

Live steam now appears to be very satisfactory, especially where exact control of final volumes is not demanded. We have obtained excellent results with it. Good distribution of the steam is essential. This is accomplished by admitting it at the bottom of the cooking vessel through fine holes in a good-sized horizontal T or S. The escaping steam aids in the stirring. It also permits the use of wooden vessels and eliminates the provision for shrinkage-water, no excess being necessary when live steam is used. On the contrary some provision may need to be made for a small increase in volume by condensation during the early stages of the cooking, though this is usually not important. Enough pressure should be used to develop a vigorous boiling and avoid unnecessary condensation. One can determine when boiling begins either by a thermometer or by noting the difference in the rising steam.

Where more accurate control of final volumes and greater densities are desired, the steam may be used in closed coils or in steam-jacketed kettles with or without mechanical agitators. Such kettles, holding 100 gallons and upwards, are obtainable from the H. W. Dopp Co., Buffalo, N. Y.; or Stuart & Peterson, Burlington, N. J. They are rather costly, however, if purchased new.

The Measuring Stick.—This is for use in determining the volume of material in the kettle at any time by means of its height. It enables one to know when the desired volume is reached, and is also a convenience in adding the right amounts of water. It may be made by planing down a good lath to about 3-8"x7-8" in cross section and then accurately marking on it the heights reached in the kettle by 6, 8, 10, 12, etc., gallons of water. It is well to notch these marks, making the heights prominent that are most used.

The Hydrometer.—This is an instrument much like that used in testing acids in dairy work, but with a wider range, and is used in determining the density of the concentrate preparatory to dilution. Only instruments of reliable make should be used. Their general character is shown in Figure 2.

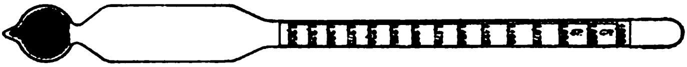

Figure 2

A convenient type of hydrometer for liquids heavier than water, used in finding the density of the concentrate preparatory to dilution. Obtainable from Bausch & Lomb, Rochester, N. Y.; Geo. D. Feidt & Co., Philadelphia; or from Eimer & Amend, New York City.

These instruments are made in two scales, the Specific Gravity and the Baumé, both of which may be placed on the same instrument. Densities are expressed by the former in decimals and by the latter in degrees. The Baumé scale is somewhat easier to read, but the other is more convenient to use, inasmuch as the required dilutions can be obtained more directly from it. A desirable range is from 1.000 to 1.32 or 1.35 on the Specific Gravity scale or from 0 to 35° or 38° Baumé. Such instruments have been put up according to these specifications, and may be obtained from the firms indicated above. They are simple in use and indispensable in the accurate dilution of concentrated solutions.

The Strainer.—Any ordinary lime-sulphur strainer of about 30 to 40 meshes to the inch will be satisfactory. A good type is shown in Figure 3. It may be used for either lime-sulphur or Bordeaux, and the central portion lifting out greatly facilitates the cleaning.

If the strainer is to be used for lime-sulphur only, tinned iron wire will be best for the screen. If, however, it is used for both Bordeaux mixture and lime-sulphur, brass wire is best. If kept properly cleaned immediately after use (which should be done with all metallic implements when lime-sulphur is used), it will last indefinitely. An improvement might be made by sloping the upper surface of its floor toward the spout, and its size may well be increased where large quantities of material are to be strained.

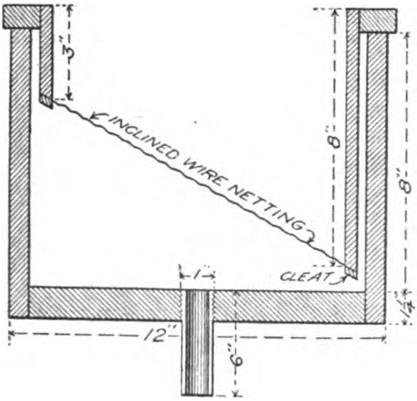

Figure 3

A satisfactory strainer easily made. (Modified from Alwood.) Wire cloth for the screen may be obtained from Hall & Carpenter, Philadelphia.

Details of Preparation.

In making fifty gallons of concentrate the procedure is as follows:
Materials:

50 ℔. best stone lime (kind stated above).
100 ℔. sulphur (kind stated above).
50-55 gallons of total product, at finish.[1]

Put 10 gallons of water in kettle and start fire. Place lime in kettle. After slaking is well started add the dry sulphur and mix thoroughly, adding water enough to maintain a thin paste, which requires about five gallons. After the slaking and mixing are completed, add water to the height of about 50 gallons on the measuring stick, bring to a boil, and stir until the sulphury scum practically disappears. Then add water (preferably, but not necessarily, hot) to about the 60-gallon[2] height and boil again to 50 gallons, if storage space is limited. If it is not limited, a little more water may be added the third time and boiling stopped at about 55 gallons. The material should be kept well stirred, especially during the early stages of the process, and any lumps of sulphur or lime should be thoroughly broken up[1].

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[1] These volumes should be obtained at least approximately, if the concentrate is to be stored. If it is to be used at once, somewhat less attention to final volumes is required, merely diluting the product according to density.

[2] The addition of water here is intended just to permit the additional boiling required and reach the desired volume at the close. The amount, therefore, should be varied to suit the particular conditions involved. If cooker is large enough, the whole amount of water may be added immediately after mixing in the sulphur, thus avoiding the check in boiling, though greater care is required to prevent boiling over. A 75-gallon cooker is large enough for this, if fire is well controlled.

If live steam is used, the manipulation is essentially the same, except that no excess of water over the final volume need be added.

The time of boiling should be until the sulphur granules are evidently dissolved. This fact is best determined by dipping and slowly pouring some of the material, under close observation. In many cases we have obtained as complete dissolving of the sulphur in forty minutes of actual boiling as was obtained by any time up to two and a half hours. In general in our work a period of fifty to sixty minutes of vigorous boiling has proved entirely safe and sufficient to put the sulphur into solution. There is no objection to a 10-minute variation in either direction provided the sulphur is evidently dissolved. Either too little or too much boiling is objectionable, however, as explained later. Hence, as indicated in the footnote, the amount of water added in the third addition should be so regulated as to permit only the necessary amount of boiling and approximately reach the desired volume at the close. This gives the least sediment and the regulation is easily accomplished after a few trials.

In case of any uncertainty, the orchardist may familiarize himself with the appearance of the sulphur at various stages and approximate the right amount of boiling under his own conditions by making up two or three batches[2], in which the cooking is continued beyond what is probably necessary. In these trials, samples of the concentrate should be taken after about 40, 50, 60, 70, and 80 minutes of actual boiling, putting the samples into clean glass vessels, and recording with each the time of boiling and volume of concentrate when taken. The latter should be kept as uniform as possible. The samples should be protected from air as usual, and be large enough to enable their densities to be determined with the hydrometer.

By studying the samples after a couple of days, comparing their densities, the character and relative amounts of their sediment, and the total volumes of diluted spray obtainable from the concentrate at the time taken, the proper time of cooking under any special conditions can be satisfactorily determined, and along with it there is gained a knowledge of the details of preparation that can scarcely be obtained in any other way.

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[1] If trouble is experienced with lumps or pellets in the sulphur, it can be considerably reduced by previously sifting the sulphur through a fine screen.

[2] The final products of these trials may be used like any other lots.

The finished product may be immediately poured or strained into a barrel or settling tank or into the spray tank. The straining is merely a safeguard to prevent possible clogging due to imperfect materials or failure to break lumps in the sulphur. When properly made, the amount of sediment or sludge left in the strainer is insignificant and may be thrown away. To avoid any considerable loss of materials, however, it may be washed with part of the water used in making the next lot, simply pouring the water through the strainer into the kettle, and any lumps of sulphur discovered may be broken up and used again.

Made as above with good materials the density of the 50-gallon concentrate averages slightly over 1.24[1] Specific Gravity (about 28½° Baumé), with that of the 55-gallon product slightly less. Much greater densities than these are obtainable by further reducing the volume of water in the concentrate, but they are unnecessary in the home product, and their attainment generally involves a *loss in utilization of materials* as measured in number of gallons of diluted tree spray.

The Sediment.

The sediment is composed largely of calcium sulfite together with some sulfate, and the magnesium, iron, aluminum and other insoluble impurities in the materials used. It also contains whatever lime or sulphur remains undissolved. It is of apparently little or no value as a spray material against insects[2], hence its volume and removal, especially in the commercial preparations, become matters of importance. Its volume is affected chiefly by the ratio of lime and sulphur; the purity of materials; and the time of boiling. Its relative volume also naturally increases with the density of the product. Either too much or too little boiling increases the amount of sediment. The influence of the former is readily shown by vigorous boiling of a clear concentrate. The latter's effect is due to failure to get all the lime and sulphur into solution. This failure results also in loss of density and is likely to be responsible for some crystallization and harshness of sediment through the presence of uncombined lime.

Made with the ratio and kind of materials described before, the actual volume of sediment has averaged in our work distinctly less than ten percent of the final product, though its apparent volume as seen in the concentrate is considerably greater. An allowance for it in diluting those sprays in which certainty of strength is important may be made, as indicated on page 13.

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[1] This means a solution which is one and twenty-four hundredths times as dense as water, or in other words one that is 24 per cent. denser than water. For additional explanation, see discussions under "hydrometer" and Process of Dilution.

[2] Parrott. N. Y. Geneva Bul. 320:428.

In the home preparation the difficulty of its economic removal and its fineness and apparent lack of objectionable mechanical qualities, except in displacing valuable materials, have led us to disregard it. It also has some value as a marker, though it is less adhesive than the clear solution. If so desired, however, its removal may be accomplished fairly well by letting the concentrate settle for about a day, drawing off the clear portion and straining the remainder through a fine screen or through a moderately fine cloth inside the strainer. The sludge may then be washed free of any further valuable materials in the manner stated above.

The Preservation of Lime-Sulphur.

When properly handled, lime-sulphur solutions apparently can be preserved indefinitely. A sample of material made by us on February 1, 1909, of 1.336 density (36½° Baumé), has remained thus far without apparent change, though kept at outdoor temperatures until the middle of December. Ordinary changes in temperature have little permanent effect on them[1].

But they are very sensitive to a number of other influences. Continued exposure to air, for example, results in the development of a crust of solids of varying thickness. This is prevented by *cutting off the air contact before the concentrate cools* either by a thin oil covering (paraffin oil or any heavy oil being satisfactory), or by immediate storage in tight closed vessels, filling them completely. When the crust does develop it can be skimmed off with a fine screen and readily redissolved by heating either in water or in the concentrate itself.

These solutions are also decomposed in a number of other ways. Acids, carbon dioxid, certain arsenicals, and even extra lime put in as a marker, all appear more or less rapidly to break down the lime-sulphur combination. This is not always fatal in practical results, but we believe it is to be avoided when possible. Most of them can be avoided by elimination.

Arsenicals.—In the case of arsenicals, however, their addition is necessary when the material is used as a summer spray. The addition of arsenate of lead results in very rapid decomposition, both of itself and the lime-sulphur. The resulting compounds in some cases have given good results practically, however, so that the combination is not unusable, provided sufficient strengths of both ingredients are used.

---

[1] In our experiments, solutions of 1.22 density froze at about 14° F. and 1.28 solutions at 5° F. They recovered completely in nearly all cases. Such temperatures are objectionable however, where there is danger of bursting the container.

But in at least one case, the practical efficiency of the arsenate has been very materially reduced[1]. It also seems to be a very wasteful process, especially when we can obtain the same poisoning power in another arsenical, the arsenite of lime, for about one-sixth the cost. Also during the time required, the latter arsenical is practically stable in the lime-sulphur solution. It has been in use to a greater or less extent for a long time in connection with other fungicides, but has been limited by a tendency to burn foliage, this being due to free arsenic remaining after faulty methods of preparation or use. The burning is practically avoided by making it up with a slight modification of the Kedzie formula, as follows:

White arsenic[2]	2 ℔.
Sal soda[2] crystals	2 ℔.
Water	1 to 1½ gal.

Boil until entirely dissolved, which requires about fifteen minutes. Use this solution to slake three or four pounds of good stone lime. If this slaking is properly done, the arsenic will be combined very effectively[3], and the arsenite of lime thus formed will retain its strength indefinitely. When ready for use, add water to the product to bring the total up to two gallons, and stir thoroughly. Two pints of the well stirred, uniform mixture will then evidently contain one-eighth of the original materials or one-fourth pound of white arsenic, in the form of arsenite of lime, which is equal to one-half pound of Paris green. This amount is ample for 50 gallons of diluted spray for codling moth, and it may be added immediately after dilution.

The use of Paris green in the lime-sulphur solution, we believe to be undesirable. It is unsafe, unstable and uneconomical.

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[1] Northwest Horticulturist, Feb. 1910, p. 32. Melander of the Washington Station, using the materials close to their limit of efficiency, 1 lb. to 66 gal., reports 22 per cent. worm-free fruit with a combined spray of a lead arsenate and lime-sulphur as compared with 47 per cent. worm-free with the arsenate alone at a slightly greater dilution.

[2] Obtainable from Powers-Weightman-Rosengarten Co., Philadelphia, or from other manufacturing chemists.

[3] By this method we have been able to reduce the soluble arsenic to a mere trace, .013 per cent. after 30 minutes of agitation in water with air bubbling through it.

The Lime Marker.—The addition of extra lime as a marker is objectionable mechanically and apparently also chemically, and the practice appears to be gradually being abandoned by many experienced orchardists. Its addition seems to break down the higher sulphur compounds[1], and is especially bad where much magnesia is present in the lime.

Its use appears to be entirely unnecessary in the summer fungicide, and even in the dormant insecticide its "marker-value" is seriously reduced by the objections stated above. If the marker is desired, however, despite the objections, it can be obtained by adding about three to six pounds of good lump lime or four to eight pounds of dry-slaked lime to 50 gallons of diluted spray, making the addition as near as practicable to the time of application.

The Process of Dilution.

In the application of any concentrate, either home-made or commercial, it is essential that a definite method of dilution be followed. Two solutions may look exactly alike and yet differ widely in density, so that any accurate method must be based primarily on the density of the concentrate that is being diluted. Moreover, we believe that recommendations based on density of diluted spray are preferable to those based on number of dilutions even when accompanied by a statement of the concentrate's density.

Accurate dilution is very simple and easily accomplished with the aid of a hydrometer having a Specific Gravity scale[2]. Sprays of any desired density may be obtained from any concentrate by simply getting the reading of the concentrate and dividing the decimal of this reading by the decimal of the spray desired. For example, if the reading of the concentrate is 1.27 (about 31° Baumé), to get a spray of 1.03 density we divide the .27 by .03 and obtain *nine*, which is the number of dilutions required and which of course is obtained by adding ***eight*** volumes of water. In this we are simply applying the general fact that the density of a solution heavier than water varies inversely with the number of dilutions.

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[1] New York Geneva Bul. 319:406-9. Some decomposition and loss of sulphur in the form of hydrogen sulfid (H_2S), especially during the boiling, is attributed to the presence of magnesia.

[2] The presence of foreign soluble materials or of much roily sediment in the sample will reduce the value of the test, a fact which must be taken into account—the former especially in solutions of unknown preparation. Also for exact work the temperature of the concentrate should be within about 10° of the temperature on the hydrometer.

The workings of the process may be seen further in the following:

(A) To determine number of dilutions.

$$\textbf{Rule:}\quad \frac{\text{Decimal of concentrate}}{\text{Decimal of Spray desired.}} = \text{Number of dilutions.}$$

$$\textbf{Examples:}\quad \frac{(1).24}{(1).03} = 8,\ \text{or}\ \frac{(1).25}{(1).01} = 25,\ \text{or}\ \frac{(1).30}{(1).03} = 10,\ \text{or}\ \frac{(1).30}{(1).003} = 100$$

(B) To determine density of spray used.

$$\textbf{Rule:}\quad \frac{\text{Decimal of concentrate}}{\text{Number of dilutions.}} = \text{Decimal of Spray.}$$

$$\textbf{Examples:}\quad \frac{(1).26}{10} = .026.\ \text{Therefore spray} = 1.026\ \text{Specific Gravity.}$$

$$\frac{(1).27}{50} = .0054.\ \text{Therefore spray} = 1.0054\ \text{Specific Gravity.}$$

This method gives final sprays of definite density and the importance of this is obvious when we consider the relatively small margins between safe and unsafe densities in the use of these solutions on foliage. It applies directly, however, to the dilution of clear solutions or to sediment-containing solutions in which a slight additional weakening of the derived sprays is not serious. This is the case with most of the sulphur fungicides. With other sprays, such as most insecticides, wherever there is danger of over-dilution, an allowance of about 10 percent for the sediment may be made. This allowance is usually more than provided for by reducing the indicated dilution by one volume. Thus for scale, a clear 1.24 concentrate should be diluted about 1 to 8, while one of the same density containing the normal amount of sediment would be diluted one volume less, or 1 to 7, which is obtained by adding 6 volumes of water.

In making the dilutions we have found that diffusion of the sulphur compounds takes place rather tardily, especially if the water is added without much commotion. This behavior necessitates a thorough stirring or agitation, even of the clear solution, to avoid inequalities in the spray as applied. It also apparently renders inadvisable any method of dilution which contemplates the use of a hydrometer floating in the liquid to determine when the right amount of water has been added.

With Baumé hydrometers, the dilutions are obtained indirectly either by conversion into the Specific Gravity scale[1] or by means of special dilution tables.

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[1] Conversion tables may be obtained by application to Elmer & Amend, New York City; Bausch & Lomb, Rochester, N. Y.; or other hydrometer manufacturers.

The following table gives uses and approximate practical densities for the lime-sulphur spray, as determined by foliage tests here and other present available results both here and elsewhere.

Table 1

TIMES AND STRENGTHS OF SPRAY FOR VARIOUS PURPOSES

INSECT OR DISEASE	SPRAYING TIMES	DENSITY OF SPRAY
San Jose scale	Trees dormant, but best in fall or spring[1]	1.03 for regular annual control. 1.04 in bad cases, especially on old apple trees.
Oyster-shell scale	At hatching time.	1.02. Also as above.
Blister-mite	Just before buds open.	1.03.
Plant lice	" " " "	1.04[2]
Peach leaf curl	" " " start.	1.02 or 1.03.
Apple and pear scab Apple worm—add arsenical in 2 and 3.	(1) Blossoms beginning to show pink. (2) Within a week after blossoms fall. (3) About three weeks later.	1.01. May be varied slightly either way, as results indicate.
Cherry leaf spot	Three sprayings, a month apart, beginning with signs of infection[3]	1.01, or slightly weaker.
Suggested combination treatment[3] for: *Brown rot*, *Curculio* and *Scab* of stone fruits. (Experimental on peach and plum with (2) and (3) as yet).	(1) When calyces ("shucks") are shedding, lead arsenate, lime and water, 2-2-50. (2) About a month after petals drop. Lime-sulphur and arsenical. (3) About two weeks before fruit ripens. Lime-sulphur only.	About 1.003[4] Varied as results direct. For arsenical in (2) see pp. 10-11. One pint of the arsenite should be sufficient for 50 gal. Effects on foliage may be tested about 10 days in advance of regular applications.

The densities given in the table should prove efficient and safe where *pure* solutions are used[5]. They are not infallible, however, and in view of the present stage of development of the subject some revision is to be expected. The chief uncertainty is in the proper strengths for summer use on the tenderer stone fruits. With them it seems probable that protection of the fruit against brown rot will be secured only at some sacrifice in foliage, though this is not definitely settled. Also we have noted occasional injury to apple foliage from third and fourth applications when earlier treatments at the same strength had proved entirely safe. Moreover, an abundant application may sometimes affect foliage nearly as much as the density of spray applied, through the collecting of spray into drops which evaporate to injurious densities. On these accounts, it is difficult to make any schedule of densities on foliage that will be safe under all circumstances. In general, however, the densities named should prove a satisfactory beginning for average conditions and may be varied if necessary as later results direct.

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[1] March applications were 41 per cent. better than those in January, in Forbes' results. Ill. Bul. 107.

[2] Colorado Bul. 133:27. Apparently not always completely successful.

[3] Based on Scott's recommendations for control with self-boiled lime-sulphur, (with slight modifications). Bureau of Plant Industry, Bul. 174.

[4] This or an even lower density is indicated to be practical in Whetzel and Wallace's work at Cornell.

[5] The presence of salt or other foreign materials in a preparation may modify the safety on foliage as well as the efficiency of some of these densities.

William [illegible]ck

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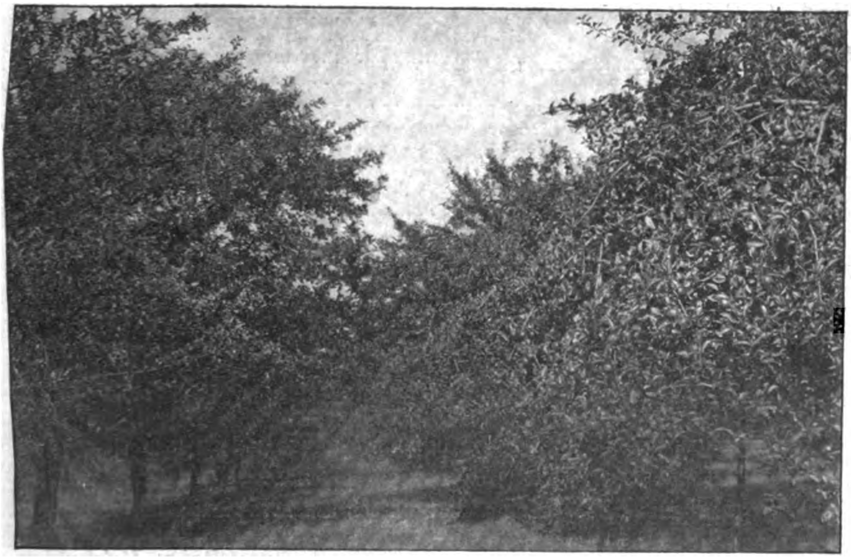
The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 100



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THE FERTILIZATION OF APPLE ORCHARDS

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
JUNE, 1910

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 100

THE FERTILIZATION OF APPLE ORCHARDS

JOHN P. STEWART

SUMMARY

1. Fertilizers are but one of many factors that affect success in orcharding. Among the others are soil, location, varieties, cultural methods, thinning, spraying, pruning and general orchard care.

2. The weakest factors largely control and limit the crop and through them it can be affected. Consequently, the value of attention to any factor is essentially proportional to its need. In general, therefore, applications of plant food will be of most value when it is the limiter. In the presence of other still weaker factors its effect may be wholly lost.

3. The best orchard treatment probably consists in the discovery of the crop-limiters, their elevation to the level of the other factors, and the maintenance of a properly balanced treatment thereafter.

4. The recognition of plant food as a limiter is often difficult and the fact is best determined by trial. Its need, however, may be indicated by the trees being deficient in growth, foliage or fruit after the other factors are apparently right. Under such conditions the addition of manures and fertilizers have produced most abundant results.

5. Nitrogen is apparently of much greater value in apple orchards than is generally supposed. Its addition has greatly increased the quantity of fruit. Many failures with potash and phosphate have doubtless been due to a deficient nitrogen supply. It should be used judiciously, however, because of an indirect reduction in color, and sometimes also in size of the fruit. It can be used most freely on the earlier soils or in localities with long growing seasons.

6. Nitrogen may be secured in stable manure, cover crops, or in commercial forms. If applied in very soluable forms, especially on leachy soils the time of application must be right. This is probably somewhat after petal-fall when the stored food is exhausted and the need is greatest.

7. In general, where plant food is needed, phosphate and potash should also be supplied. This prevents their becoming limiters in turn, and may also check some of the ill effects of nitrogen on the appearance of the fruit.

8. Both lime and "floats," when applied alone, have thus far failed to show any marked beneficial effects.

9. None of the fertilizers applied in our work has shown any consistent ability to improve color or size of fruit. Color is doubtless chiefly dependent upon maturity in sunlight, while average size is apparently mainly dependent upon the amount of moisture available per individual fruit.

10. Our present general recommendation of fertilizer for apples in this state, in amounts per acre, is the following combination: 30 pounds of actual nitrogen, 60 to 75 pounds of actual phosphoric acid (P_2O_5), and 50 pounds of actual potash (K_2O)[1]. This may well be supplemented by cover crops, through which all the nitrogen may be obtained, and alternated with stable manure at the rate of about 10 tons per acre at least every third or fourth year.

11. Proper moisture conditions are essential to the securing of best results from fertilizers. In most places moisture conservation is best accomplished by the soil or dust mulch maintained by frequent tillage. Where tillage is inadvisable, it can also be done very satisfactorily with a good mulch of foreign materials, such as straw, chaff, leaves, manure or dead weeds.

12. Leguminous crops apparently make less draft upon soil moisture than the grasses or cereals. This, together with their fav-

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[1] For combinations carrying these amounts, and other details, see pages 26 and 27.

orable nitrogen relations, makes them decidedly preferable to the latter in apple orchards, whether used as intercrops, cover crops, or permanent covers in connection with a mulch.

13. Accompanying the fertilization above, a good plan of soil management for many situations is tillage with a leguminous cover crop while the orchard is young, followed by a mixed grass and leguminous sod-mulch when bearing age and size is reached. After the bearing habit is established, a return to tillage at least every second or third year should be made, increasing the frequency of tillage with the age of the orchard and the demands of the fruit.

14. Current orchard practice may be improved by the owners adopting the methods apparently best for their orchards as a whole, and then maintaining some parts for experimentally determining whether the methods chosen are really best for their conditions.

The Viewpoint.

Economic production of first grade fruit is largely a matter of properly balanced treatment. In every orchard the crop of best fruit is reduced by some one or more weak or limiting factors, and because of their presence. much of the care devoted to the others is lost. The truth of this is shown in figures gathered by us on the relation of profits in apples to cost of production and marketing. These figures show that net profits have actually increased with expenditures up to more than $300 per acre,—a result evidently due to having all factors right.

Balanced treatment of an orchard is best secured by giving first attention to the limiters. Through them the crop can be affected. And, in general, the value of attention to any factor may be regarded as essentially proportional to its need. Evidence on this appears in the following pages. Applications of plant food for example have in some instances produced practically no effect ,while in others its addition has resulted in more than quadrupling the crop[1].

The recognition of limiters is easy in many cases. This is true of reductions due to insects, fungi, blight, frosts, improper location, failure to thin, stubby or "cowtail" pruning, and general neglect.

With some other factors, however, their status is not so obvious and it can only be definitely determined by trial or experiment. Among these are included requirements for plant food and moisture. That at times they may become very powerful limiters is beyond any reasonable doubt, and with them we are concerned in this report[1].

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[1] See Tables IV and VI.

Extent and Bases of Orchard Fertilization.

In the country as a whole, orchard fertilization is not being neglected. At the time of the last census the amount thus expended was about $2,000,000 per year. Fruit farms expended 30c per acre for fertilizers as compared with 4c on hay and grain farms and 2c per acre on stock farms. Since then this expenditure has doubtless largely increased. But in making it, we have no definite system of orchard fertilization and little accurate data of broad derivation upon which one may be based.

The systems of fertilization now in operation or recommended are based on four things: (1) analysis of trees and their crops; (2) general experience and observation; (3) orchard surveys; and (4) experimental studies. Each has its strong and its weak points. For example, analyses show that an acre of bearing apple trees takes up about 55 pounds of potash (K_2O) per year. But the fact that they have this potash does not prove either that they must have it or that its addition to the soil would secure any material response. Indeed, the same analyses show the annual possession by the trees of 57 pounds of lime per acre, and yet lime is not generally considered important in orchard fertilization.

There are similar weaknesses with the other sources of evidence. General experience and observation fail because of their lack of checks and their local application. Orchard surveys furnish the wide application and are therefore very valuable. But they cannot completely isolate any one factor, and they are confined to current practice. Experimental studies are confined to comparatively few trees and soils, hence, must be more or less local. They also require considerable periods of time. But in spite of defects, each line of evidence contributes something and the final solution of the problem will be based upon all.

In this discussion, we are concerned with experimental evidence. The apple is not an easy crop to deal with experimentally. The difficulty of getting uniformity in soil and varieties over the large areas required, the perennial nature of the plant with its resulting food storage for early spring growth, the continuous cropping without chance for rotation, and the sensitive and fickle bearing habit are some of the difficulties that must be met. They make it necessary to forget many of the methods found applicable to other crops, and require that the whole problem be studied anew.

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[1] This bulletin continues the work reported in our Bulletin 91, the supply of which is exhausted. Those portions of the latter necessary to an understanding of the work as a whole are retained here, with more or less modification. See also Annual Station Reports for 1907-9.

Present Experimental Data Elsewhere.

In view of these difficulties there is a very fair amount of experimental data already at hand. Three valuable long-time experiments have been made.

The first of these has been in operation at the Woburn Experimental Fruit Farm in England since 1894. Up to the close of the 14th season, there has been almost total absence of effect from manure of any kind. In a more recent test on poorer, sandy soil they report that manures and especially stable manure, are having a very beneficial action[1]. The absence of effect in the longer experiment was explained by "the fact that trees draw their nourishment from a very large area and from a very considerable depth, ***** and, hence, are very little affected by surface dressings"[1].

This experiment is of value in showing that some orchards are limited by something other than manures and fertilizers. It is also interesting in the fact that while the experiment as a whole shows no results from manures, yet it is reported that certain July applications of nitrate of soda produced distinct effects. The applications of nitrogen in the regular experiment were made in February.

The second long-time experiment is the one made at the Geneva Station, New York, and reported in 1907 by Professor Hedrick. This gives the results of twelve years of annual applications of potash and phosphate, in the form of wood ashes, supplemented during the last seven years with acid phosphate, at the rate of 169 pounds K_2O, and 129 pounds P_2O_5 per acre. The trees were 43 to 55 years old and the soil is a medium heavy clay. The results as a whole were considered negative, since the annual increase in combined yield of all varieties on the treated plots barely paid the cost of the fertilizers and their application.

The results in detail are shown in Table I. The annual average yields per tree of the table are taken from the report[2]. The remainder of the table we have calculated from them, since the trees were set 48 to the acre.

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[1] Letter of Spencer U. Pickering, Sept., 1907.

[2] N. Y. Geneva Bul. 289:226. 1907.

Table I.

Effect of Potash and Phosphate on Apple Yields.

Annual Averages for twelve years	Baldwin		Fall Pippin		Roxbury		R. I. Greening		Northern Spy	
	Treated	Not Treated	Treated	Not Treated	Treated	Not Treated	Treated	Not Treated	Treated	Not Treated
Yield per tree..	8.78	8.50	7.23	6.18	11.16	8.51	8.58	8.72	7.90	5.35
Yield per acre..	421.4	408.	347.	296.6	535.7	408.5	402.2	418.6	379.2	256.8
Benefit, bu. per A.	13.4		50.4		127.2		-16.32		122.4	
% Benefit....	3.1%		17 %		31.5%		-3.9%		42 %	

One of the most striking things in this table is the *difference in response* to fertilizers made by the different varieties. Baldwin and Rhode Island Greening were practically unresponsive, while Northern Spy and Roxbury show an *annual average benefit* of nearly 125 bushels per acre. It did not pay to add fertilizer to the Baldwin and Greening trees, while even at the low price of $1 a barrel Northern Spy and Roxbury returned a *net profit* of nearly 180 percent annually on the cost of the fertilizer. This apparently indicates that the value of a fertilizer may sometimes depend on the variety fertilized. But it should also be remembered that only phosphates and potash were applied (if we disregard the lime in the ashes), and it is stated elsewhere[1] that "leguminous cover crops plowed under in the orchard have usually produced beneficial effects the same or the next season" and that "it needs nitrogen, or humus, or the physical condition to be obtained by plowing under organic matter." In other words, nitrogen or humus is apparently the crop limiter in this orchard, and until this need is met little or no advantage can be gained by applications of other forms of plant food. This experiment, therefore, may be regarded as showing *partial results* from the application of certain fertilizers.

The third experiment is in Massachusetts. Its consideration is deferred to page 24.

The Pennsylvania Experiments.

To obtain additional evidence, the series of experiments now in operation in this state were started by the writer, acting for the Pennsylvania Experiment Station, in April 1907[2]. Eleven orchards were located in various parts of the state, in which experiments were established. These orchards involved 12 varieties, 10 soil types and including the additional one at the college they cover 91 acres. Forty-nine acres, including 2219 trees, are in partial or full bearing. Their yields in 1908 were somewhat over 164,000 pounds of fruit, and in 1909, the third year, they were 256,000 pounds. The data for the tables and conclusions which follow, therefore, cover a period of three years and are derived from something over 420,000 pounds of fruit. The exact locations, soil types and varieties involved are shown in TableII.

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[1] N. Y. Geneva Station Bul. 289:231.

[2] The problem assigned was to determine and study the causes that affect yield and quality in apples. Our work was based upon the general proposition that the growth and development of any plant vary with the limiting factor. Inasmuch as the possible environmental limiting factors for all plants are moisture, food, heat, light, carbon dioxid and oxygen, and some of them are beyond the control of man, it was decided first to study those that are more or less within his control. We therefore are now studying (1) the influence of plant food as affected by fertilizers; (2) the influence of moisture as affected by soil management or cultural methods; and (3) the influence of cover crops. We are also making some study of the internal factor, heredity, as influenced by propagation from best individuals, and by variety.

Table II.

Location, Soil, and Other Data on Experiments away from the College.

Expt. No.	County	Owner of Orchard	Soil	Varieties	Age 1909	Number of Trees
215	Adams	Tyson Brothers	Porter's loam	York Imperial and Stayman Winesap	Yr. 10	160
216	Franklin	D. M. Wertz	Montalto fine[1] sandy loam	York Imperial and Jonathan	10	160
220	Bedford	Mrs. S. B. Brown	DeKalb stony loam[1]	York Imperial and Baldwin	11&21	160
217	Franklin	J. H. Ledy	Montalto loam[1]	York Imperial and Gano	16	358
218	Franklin	J. A. Nicodemus	Hagerstown clay loam[1]	York Imperial and Albemarle	10&14	400
219	Bedford	J. R. Sleek	DeKalb shale loam[1]	Y. Imperial, Jonathan, Ben Davis & Gano	7	320
221	Wyoming	F. H. Fassett	Fine sandy loam[2]	Northern Spy and Baldwin	37	115
336	Chester	A. D. Strode	Chester loam	Grimes, Smokehouse & Stayman Winesap	7-9	120&105[3]
337[4]	Mercer	St. Paul's Orphans' Home	Volusia silt loam[1]	Northern Spy, Baldwin and Rome	2	180 & 180
338	Lawrence	J. B. Johnston	Volusia silt loam[1]	Baldwin	21	80 & 105
339	Bradford	F. T. Mynard	Upshur loam[1]	Baldwin and Fallawater	15	120 & 16

The first three experiments, 215, 216 and 220, comprise what may be called our straight fertilizer experiments; the next four are experiments on cultural methods, with and without manures; and the last four are a combination of fertilizers and cultural methods. Each of the fertilizer experiments contains sixteen plots of ten trees each. The plan and treatments are shown in Figure 1.

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[1] Soils un-mapped as yet but probably closest to the types indicated according to the observations of C. F. Shaw and H. J. Wilder.

[2] This soil has received no series name but it is one that has been deposited in a lake bed formed by the temporary stoppage of the Susquehanna in cutting through the mountains.

[3] In the two sets of figures in this and the following experiments, the first gives the number of trees under fertilizer treatment, the second those under differing cultural methods. In experiment 339, the latter includes only a sod mulch plot.

[4] Trees set out in connection with these experiments, hence not yet in bearing.

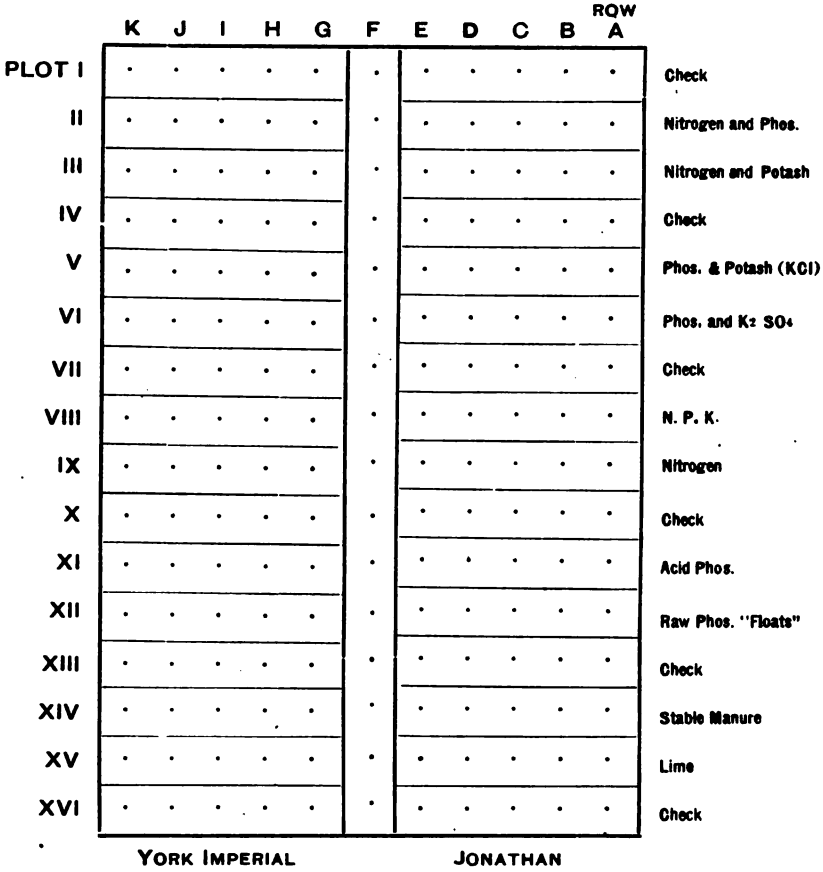

Figure 1. Influence of Fertilizers.

This experiment (No. 216) is located with D. M. Wertz, Franklin Co. Others with Tyson Bros., Adams Co.; S. B. Brown, Bedford Co.; and at State College.

The symbols N. P and K refer to nitrogen, phosphates and potash; and they are applied at the rates of 50 ℔. N., 100 ℔. P_2O_5 and 150 ℔. K_2O per acre in all cases. Plots 5 and 6 compare the muriate and sulphate as carriers of potash. Plots 11 and 12 compare acid phosphate and "floats" as carriers of phosphoric acid (phosphorus pentoxid, more correctly). The manure is applied at the rate of 12 tons per acre and the lime at 1000 pounds per acre. All applications are made annually.

The combined results to date of the first three experiments are shown in Table III.

Table III.

Influence of FERTILIZERS on YIELD, COLOR and GROWTH.

Plot	Treatment	Yields, 1908-9 Lb.	Yield, % Benefit[1]	Yields, 1909 3rd Yr. Lb.	Yield, % Benefit 3rd Yr.	% of Apples colored ½ or more[2] 1908–9	Color, % Benefit[1]	Ave. Increase per tree in trunk girth in inches 1907-9	Growth, % Benefit[1]
1	Check	4643		1306		69.2		3.29–	
2	N P	6887	78.1	1770	51.2	47.9	–22.5	3.54	8.9
3	N K	5653	82.8	1409	36.4	57.	–14.5	3.63	19.1
4	Check	2313		897		72.7		3.18	
5	P K	3577	62.5	1441	56.5	69.8	1.7	3.34	3.8
6	PK_2SO_4	2773	32.	1664	76.3	67.2	3.6	3.43–	5.1
7	Check	1998		1067		59.		3.29	
8	N P K	3847	67.4	1561	31.3	41.6	–20.3	3.97–	18.2
9	N	4709	81.2	2675	104.2	43.8	–21.1	4.08	19.4
10	Check	2898		1431		67.8		3.48	
11	Acid P.	2833	6.26	2126	52.2	69.3	3.3	3.49–	–1.7
12	Raw P.	1548	–36.6	1073	–21.3	75.3	11.	3.29	–8.9
13	Check	2209		1327		62.5		3.68	
14	Manure	4793	138.3	3423	178.5	56.0	–9.1	4.30	21.6
15	Lime	1538	–21.7	895	–21.	66.7	–.9	3.73	9.6
16	Check	1843		1034		70.2		3.26	

Striking things shown here are the strong beneficial effects of manure and of nitrogen on yield and growth, with the usual harmful influence on color. Plots 6 and 11 show surprising gains in the yields of the third year. Raw phosphate and lime continue to show deficits in every way except in color for the former and in growth for the latter. We can hardly see any reason for this harmful effect in the case of the "floats" and suspect that it is due to some temporary condition which will disappear later. The same may be true of the lime effect, though the reports of "lime poisoning" made by Dr. Headden in Colorado Bulletin 131 are worthy of consideration in this connection. It is also worthy of note that the plots which have made the best yield have also made the best growth, thus showing that reasonable amounts of yield and growth are not antagonistic but rather are associated.

A puzzling condition appears in the fact that wherever nitrogen has been applied in combination with other elements, the benefit decreases in the third year, while in plot 9 where it was applied alone the benefit in the third year increases distinctly. This is partly explainable in the larger yields of the former plots last year, thus bringing them more strongly under the operation of the biennial bearing habit.

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[1] The percent of benefit is determined by comparing the "normal performance" of each plot with the results actually secured, the normals being obtained by comparison with the two nearest checks.

[2] In all these tables, the effects on color and size of the fruit were obtained from random samples, taken from the fruit of each tree as it was weighed, the aggregate sample from each plot amounting usually to one or two bushels. The data on yield and growth have been obtained by weighing all the fruit and taking measurements twice on every tree.

But the chief cause of the difference in yield between plots 8 and 9 may be traced directly to a deficit of at least 1000 pounds that occurred this year in plot 8 of Experiment 220. This deficit was not due to the absence of apples on the trees. On the contrary an excessive number of fruits were formed on this plot, despite its heavy crop of last year. And this very fact, coupled with the excessive foliage and extreme drought of the current season, almost entirely prevented their normal development. The limited water supply was not sufficient for both fruit and foliage and the latter won in the competition. (See Fig. 9). Plot 9 was subjected to similar conditions but to a lessened degree in every way. Its original set of fruit and amount of foliage were less and its moisture situation is scarcely as severe as that of plot 8.

In Table IV we have further results from fertilizers, these being from the fertilizer portions of Experiments 336, 338 and 339, which have been running for two years only. The applications are the same as in the experiments above.

Table IV.

Influence of FERTILIZERS on YIELD and COLOR.

Expts. 336, 338, 339. **(a) Yields in Pounds, 1908–9.**

PLOT	1 Check	2 N P	3 N K	4 Check	5 P K	6 N P K	7 Check	8 Manure	6 Lime	10 Check
1908, 1st Year..	562	860	748	1118	846	2178	1067	2338	3111	2748
% Benefit[1] ...		15.1	-19.8		-23.2	100.9		46.7	42.1	
1909 Totals ...	1087	6435	6367	2502	3803	7212	2436	4600	2349	1720
% Benefit		312.7	213.6		53.3	193,4		109.7	19.9	
1909.	**(b) Color, % of Apples colored ½ or more.**									
Ave. % Color..	57.2	40.–	39.8	49.4	46.5	38.0	49.7	49.0	50.3	54.8
% Benefit		-14.6	-12.2		-3.	-11.6		-2.4	-2.8	

In general, these results corroborate those of Table III. The nitrogen plots show remarkable increases in yield; and the evil effects on color are less evident than in the earlier table. The lower benefit on yield in plot 6 is due apparently to the relatively large yield on this plot the first year, coupled with a harmful influence which potash seems to be exerting in this series of experiments. Manure shows itself to be slower in action than nitrogenous commercial fertilizers. The ab-

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[1] The results of the first year were evidently unaffected by the fertilizer treatments, but they are included for the light they throw on some of the results of the 2nd year, notably those in plots 2, 3 and 6.

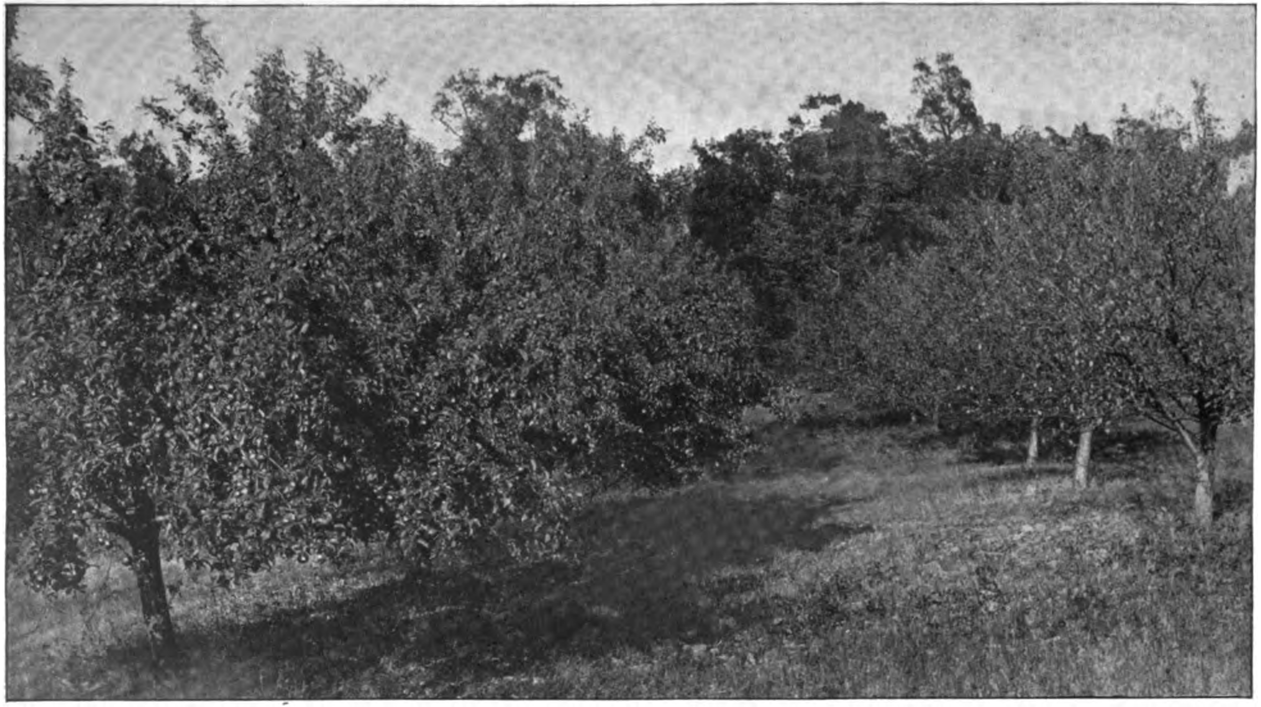

Figure 2. Manure vs. Nothing.

Row on left receiving stable manure, third year, produced 373.8 bu. per acre. Row on right, receiving nothing, produced 27.9 bu. per acre. Variety York Imperial. See pages 15 and 16.

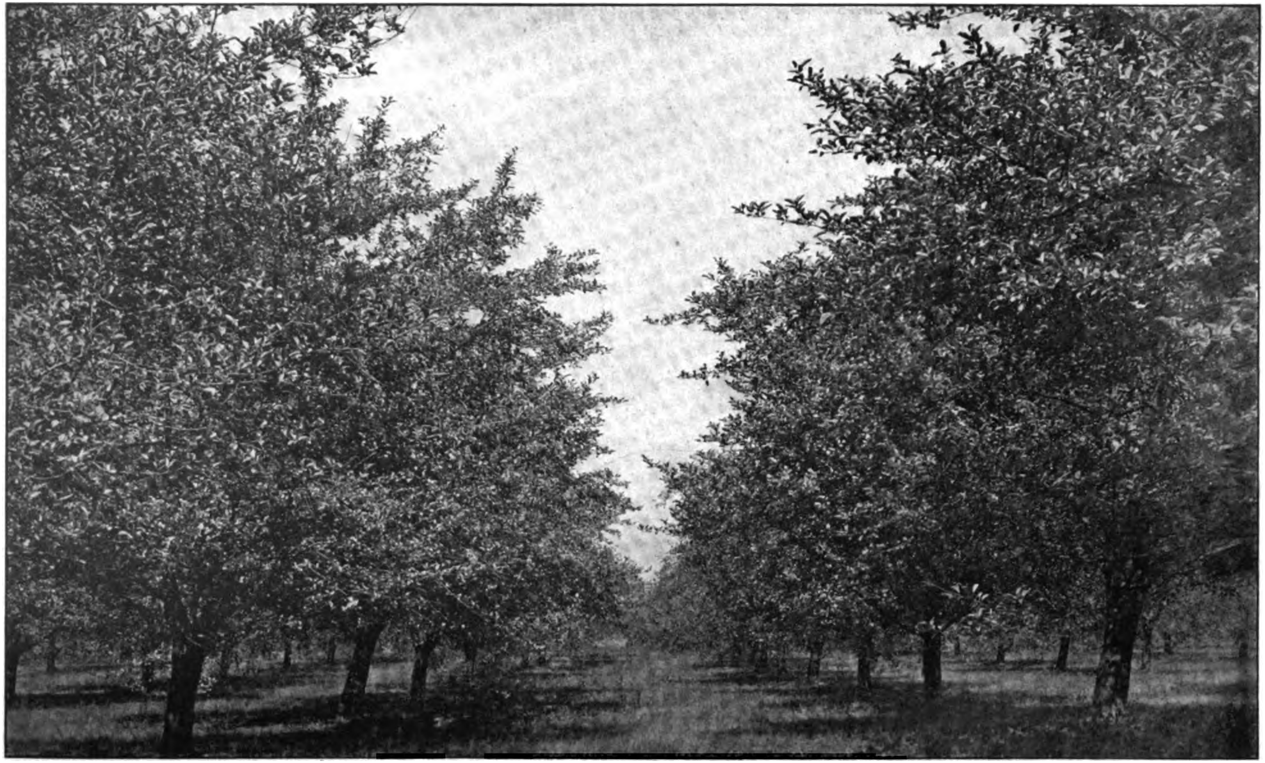

Figure 3. Commercial Fertilizer vs. Nothing.

These trees, adjoining those in the next figure, receive nothing and produced 156 bu. per acre in 1909. Variety Baldwin. Compare with Fig. 4.

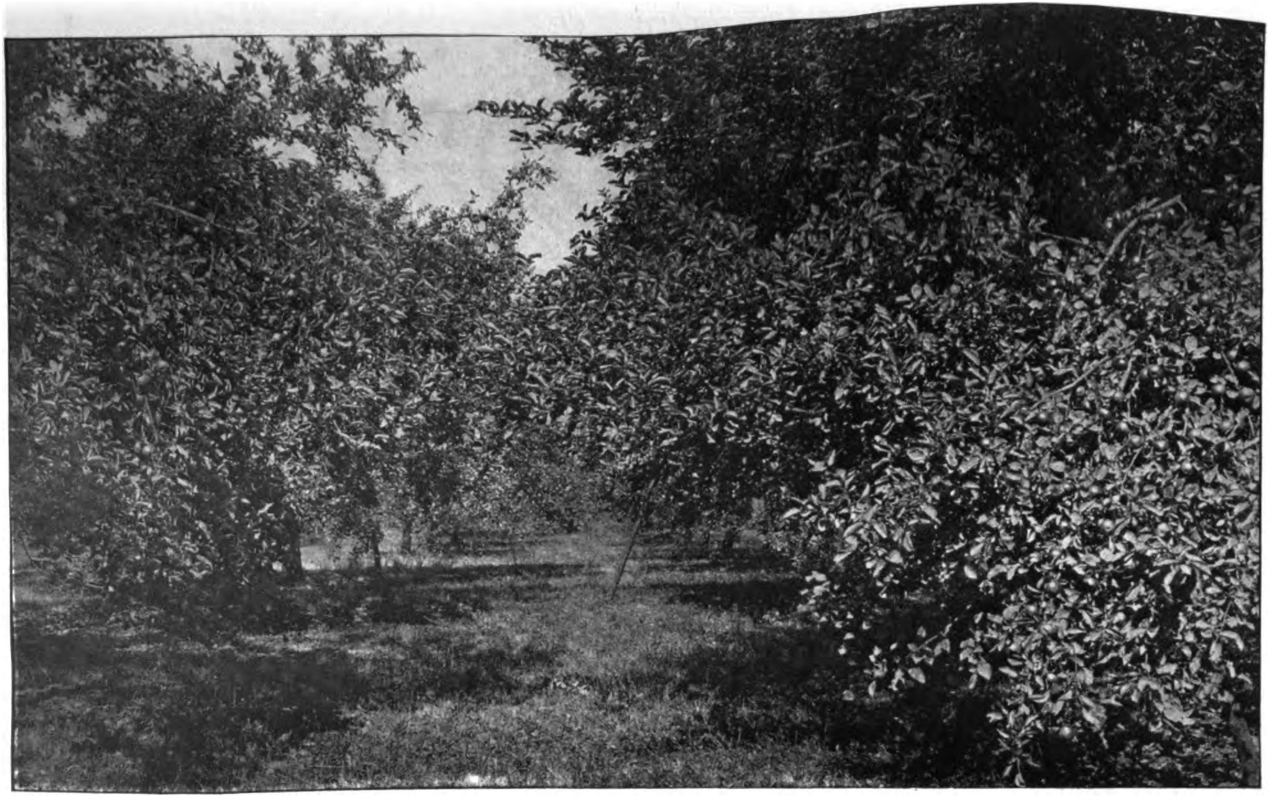

Figure 4. Commercial Fertilizer vs. Nothing.

These trees received nitrogen and phosphate and produced 721 bu. per acre in 1909. The variety and handling in all respects, except fertilization, is identical with the trees in Fig. 3. See pages 15 and 16.

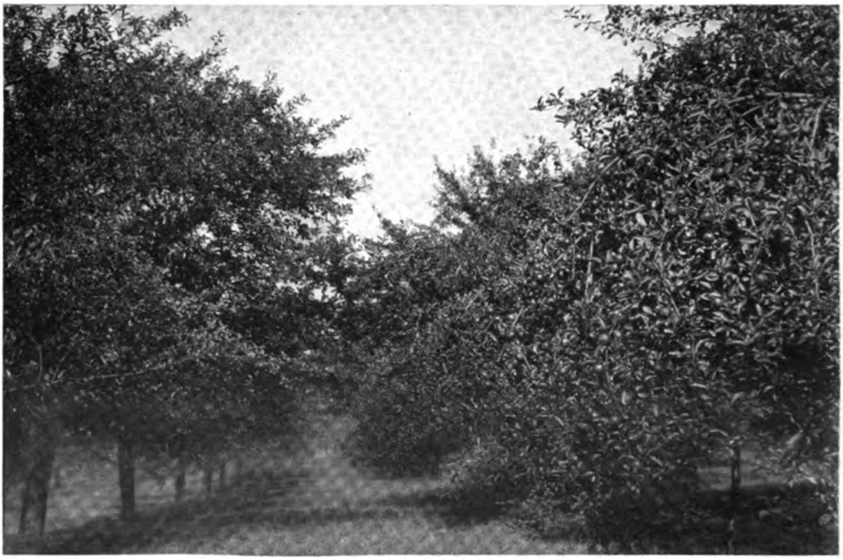

Figure 5. Commercial Fertilizer vs. Nothing.

A view between plots shown in the two preceding figures. The row on the left has received no fertilizer, that on the right has received nitrogen and phosphate. The net increase on the latter was $267 per acre. See pages 15 and 16.

sence of any well defined effect of fertilizers on the crop of the first year, is evident here as usual. The lime again shows a very weak influence, and the relatively slight benefit that appears is probably due largely to a favorable location in one of the experiments, as explained later.

Value of Different Ingredients.

Tables III and IV have shown results from various combinations of fertilizer elements, as well as some from certain materials used singly. These results being direct from the trees may be considered a close expression of the values thus far of the various combinations used. In many cases, however, we may wish to know which is the more active element in a given combination and approximately what values are to be assigned to each of the elements in it. For example, in plot 2 of Table III we find a benefit of 78% resulting from an application of nitrogen and phosphate Here the question arises as to how much of this effect was due to nitrogen and how much to phosphate. Any answer to this can be of course only an approximation of the truth and hence the values obtained and shown in the following table are not to be taken too literally. They are the nearest approach to the correct values, however, that we are able to obtain at this time and they were derived in the manner indicated in the footnote to the table.

Table V.

Influence of FERTILIZER ELEMENTS on YIELD, COLOR and GROWTH.

Estimated % of Benefit[1]

Expts. 215, 216, 220	YIELD		COLOR	GROWTH [2]
	1908-9	1909	1908-9	1907-9
NITROGEN, in combination.	49.2%	15.55%	—19.35	12.1%
" alone	81.1	104.2	—21.1	19.4
Ave. influence of Nitrogen.	65.2	59.9	—20.23	15.8
PHOSPHATE, in combination	28.9	35.65	—3.13	—3.2
" alone.........	6.2	52.2	3.3	—1.7
POTASH, in combination....	33.6	20.85	4.85	7.0
MANURE, alone.....	138.3	178.5	—9.1	21.6
LIME, alone	—21.7	—21.	—.9	9.6

Expts. 336, 338, 339 .	YIELD 1909 (2nd year)	COLOR 1909
NITROGEN, in combination	236.5%	—11·9%
PHOSPHATE, in combination	76.2	— 2.7
POTASH, in combination...............	—22.9	— .3
MANURE, alone........................	109.7	— 2.4
LIME, alone..........................	19.9	— 2.8

[2] Percent of increase in trunk girth in excess of normal increase.

[1] These values are either calculated or taken from Tables III and IV. For example, the value of nitrogen in combination was calculated by following the

These results, being derived from those in Tables III and IV, are naturally not materially different, but the values of the individual elements stand out more sharply.

Nitrogen and stable manure show strikingly beneficial effects on both yield and growth, and characteristically harmful effects on color. The effect of the manure is greatest in the third year of the first three experiments, while that of the nitrogen is astonishingly great in the second year of the three later experiments.

Phosphates show considerable value on yield, especially when used in combination with other materials. Their effect on color and growth is apparently undecided, as variations of 3% from the normal are readily attributable to limitations in our methods of determining values. Potash, in combination, has shown fairly good effects on yield and growth in the first group of experiments, but has apparently proved rather distinctly harmful in the second; and considering the results in all six experiments its value in improving color is very questionable.

Lime in the first three experiments shows a distinct shortage in yield and no advantage in color, but apparently gives a fair increase in growth. In the other experiments an apparent benefit in yield is shown. This, however, is due to an unusual increase on the lime plot of experiment 339, an increase which was due probably more to a favorable moisture situation this year than to any effect of the lime. It is surely a significant fact that in five out of six places thus far, lime shows either no effect or a distinct deficit in yield.

Color.

It will be noted that practically none of the treatments have materially improved color while a number of them have distinctly decreased it. This reduction in color is undoubtedly associated with *delayed maturity* and a *diminished light supply to the fruit*, the latter being due to an increase in the density of foliage following the application of the fertilizers.

The value of sunlight in developing redness in apples is scarcely appreciated. In a test conducted by the writer during the past fall on York Imperial apples it was found that exposure to sunlight after pick-

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formula $\frac{NP+NK-PK}{2}$. In other words, the percents of benefit obtained in plots 2 and 3 were added, from this sum was deducted the percent of benefit in plot 5. The remainder, divided by 2, is considered to be the value of nitrogen in the combination. The other values in combination were obtained similarly.

ing increased redness by over 35%, while apples confined in the dark, or exposed to electric light and under identical conditions otherwise, showed practically no increase in redness. *Maturity in sunlight* on the trees is undoubtedly the great influence affecting redness in fruit, and when soil ingredients apparently affect it, their effect is doubtless produced indirectly through some modification in the main influence.

Hence, the kind of pruning and the degree of maturity obtained before picking are the chief means at the disposal of the orchardist for affecting the amount of color in fruit.

The Appearance of Certain Experiments.

Some of the plots as they appeared in the field during the past season are shown in Figures 2, 3 and 4. Figure 2 shows a portion of plots 13 and 14 of Experiment 220. The latter plot has received stable manure for three years, while the former has received nothing. The yield of the past year was nearly 374 bushels per acre on the manure plot and 28 bushels on the check. The variety here is York Imperial.

Figure 3 is a view of one of the check plots of Experiment 338 Checks 1 and 4 produced at the average rate of 156 bushels per acre during the past year; while plots 2 and 3, located between them, produced 721 bushels per acre. Every tree on the latter plots was loaded with fruit and required heavy thinning and propping, while neither was required on any tree in the former plots. The contrast in both foliage and fruit was vastly more striking in the orchard than it appears in the figures. Plot 2, which is shown in Figure 4, received nitrogen and phosphate while plot 3 received nitrogen and potash. In all other respects the latter plots were identical with the checks enclosing them. Figure 5 shows a view between plots 1 and 2. The variety in this case is Baldwin[1].

The results shown in Figures 2, 3, 4 and 5, together with some of our other most striking results, are considered further in Table VI.

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[1] For further data on Figures 2 to 5, see Tables II, IV, and VI, with accompanying discussions.

Table VI.

FINANCIAL VALUE OF FERTILIZATION.

Expt. 221, 1909 (3rd year)	Yield lb.	Bushels per acre	Value at 50c.	Cost of Fertil'r	Net Gain per acre
Unfertilized, plots 4 and 7	19448	194.5	$97.25	$0	
Com. Fertilizer, plots 6 and 9 ..	47028	470.0	235.00	13.00	$124.75
Manure, plots 5 and 8	48550	485.5	242.75	15.00	130.50
Expt. 220, 1909 (3rd year)					
Unfertilized, plots 13 and 16 ...	291	27.9	13.95	0	
Manure, plot 14	1947	373.8	186.90	15.00	157.95
Expt. 338, 1909 (2nd year)					
Unfertilized, plots 1 and 4	2607	156.4	78.20	0	
Com. Fertilizer, plots 2 and 3 ..	12026	721.5	360.75	15.00	267.55

It is to be noted that the net gains are obtained after deducting both the cost of the fertilizer and the value of the unfertilized crop. Also the fruit here is valued at 50c per bushel, while the actual prices obtained for it varied from 50c to $1.25 per bushel, and any increase in the appraisement of the fruit of course will proportionately increase the net gain. It is also to be stated that in experiment 338 especially, variations in the factors of tillage, spraying and pruning produced no material effect on the *size* of the crop, since the treatment of all plots in these respects was uniform, and tillage was varied in other portions of the experiment.

Such striking results as these of course are not to be expected everywhere. They evidently occurred here because plant food was the crop limiter in these orchards. For any given case this can only be determined by experiment. These orchards are on three diverse soil types. The soil in one case was evidently "run down"; in another case it was in average condition; and in the third the soil condition was apparently above the average. These orchards are from 21 to 37 years of age and they are the only ones under experiment above 20 years old. Age, however, is not a sure index of the need of plant food, as one of our youngest orchards, a seven-year old, is responding strongly to fertilization, while some older ones have proved unresponsive. The big fact is that when such results as these are obtainable anywhere, it raises a strong suspicion that similar benefits may be obtained in many other orchards. And these results show beyond peradventure that in some orchards apple trees, like other plants, respond strongly and directly to applications of plant food.

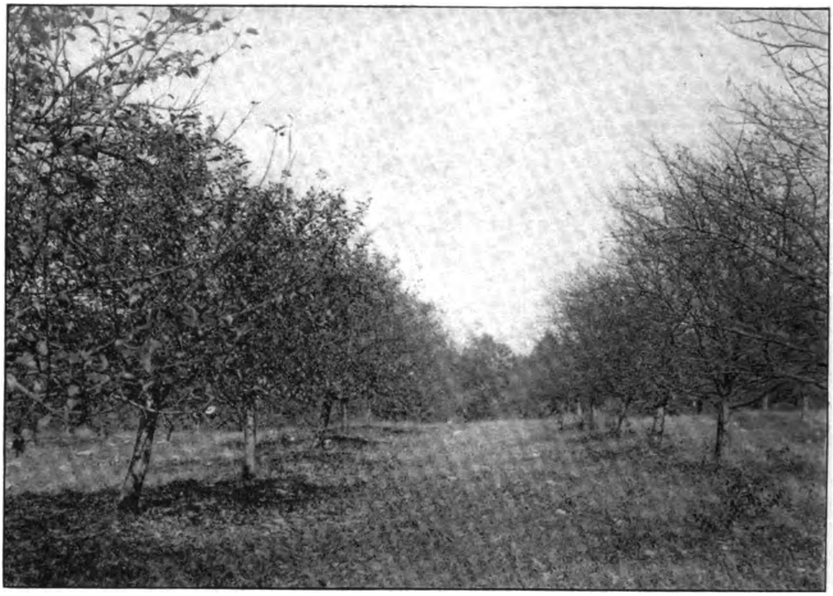

Figure 6. Phosphates and Potash (muriate) vs. Nothing.

The row on the left, plot 5, has received the fertilization, with potash in the muriate form, while that on the right, plot 4, has received nothing. See page 25.

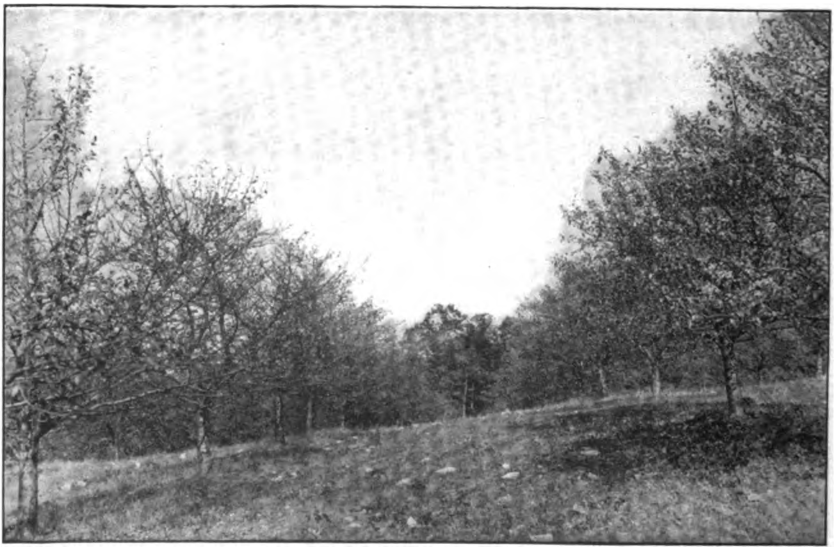

Figure 7. Phosphates and Potash (sulfate) vs. Nothing.

The row on the right, plot 6, has the fertilization, while that on the left, an unconsidered row, has received nothing except what was carried from the row above by drainage and leaching. See page 25.

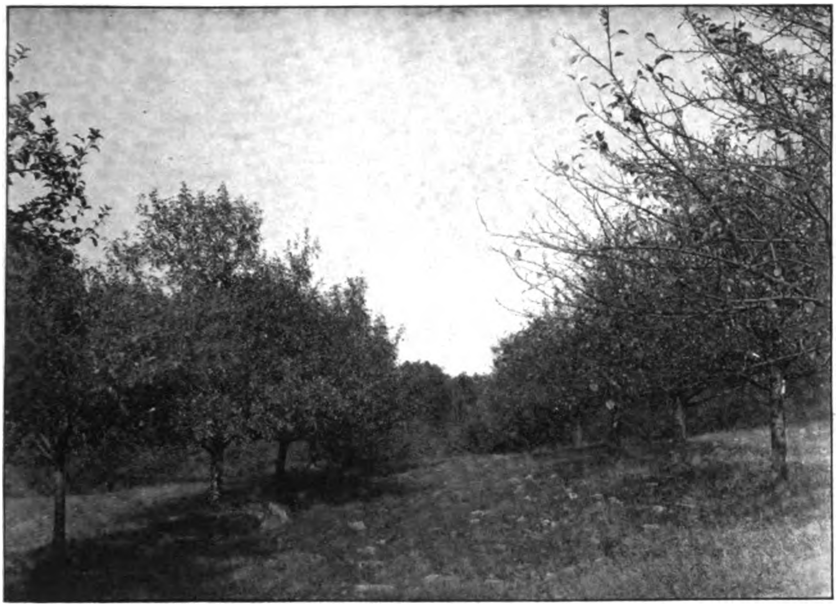

Figure 8. Nitrogen, Phosphate and Potash vs. Nothing.

The row on the left, plot 8, has received the fertilization, while that on the right has received nothing. Scarcely a leaf had fallen on plot 8 when the picture was taken, Oct. 20, 1909, and the foliage was very deep-green and luxuriant. It was in competition with this foliage that the fruit failed to attain size. See pages 12 and 25.

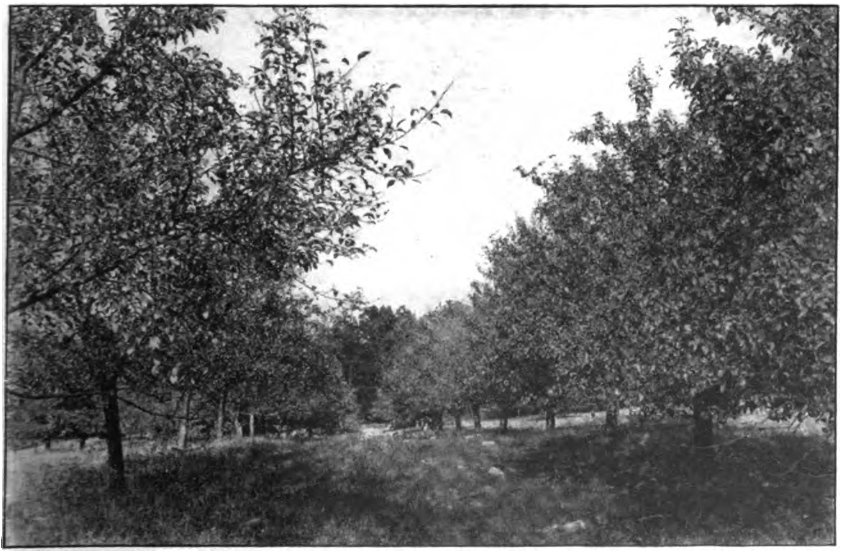

Figure 9. Nitrogen (on right) vs. Nothing.

The row on the left is an unconsidered row in this experiment, and receives no fertilization except through leaching from the nitrogen plot above. This has been sufficient to produce quite distinct effect, however. Some leaves had fallen on the nitrogen plot, and their color was not so deep green as in plot 8. See page 25.

Experiments on Cultural Methods.

Closely associated with the question of plant-food, is that of soil moisture. Unless it is present in sufficient amounts, the value of all other operations may be greatly reduced. It is the available quantity of moisture per apple that determines in a large measure whether or not the fruit shall attain its proper size; and it is largely to modify moisture-supply that the various cultural methods are followed. The plan of our experiments comparing these methods is shown in Figure 10.

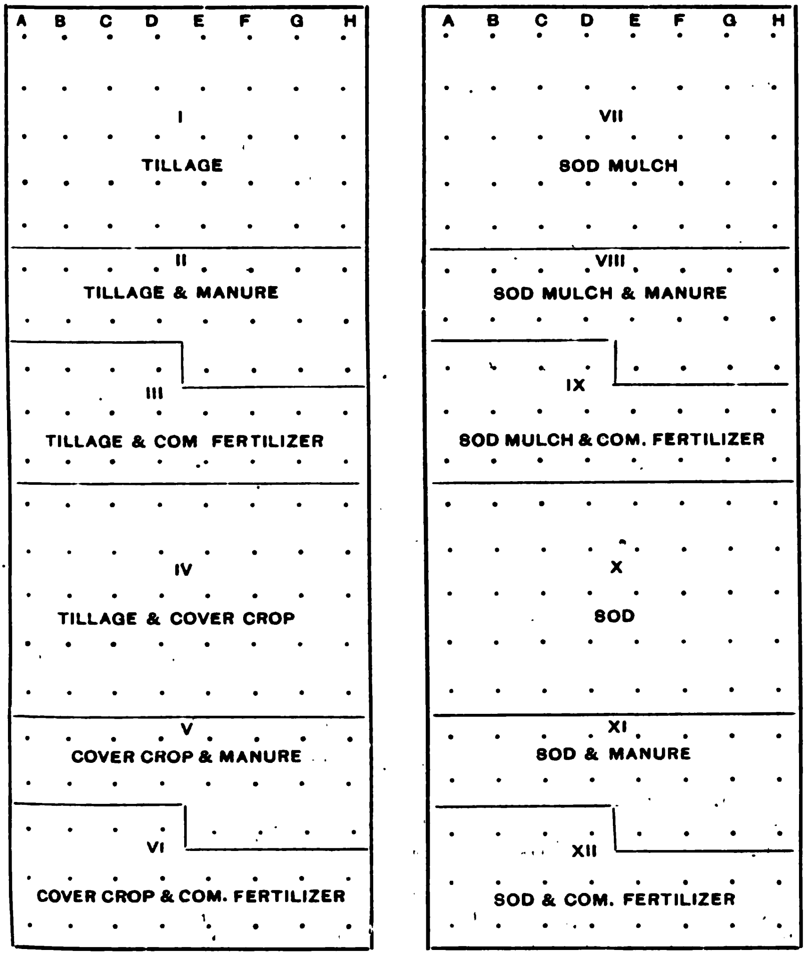

Figure 10. Influence of Cultural Methods and Manures.

The experiment figured here (No. 219) is located in Bedford County with J. R. Sleek. Others with J. H. Ledy, and with John A. Nicodemus, Franklin County; with F. H. Fassett, Wyoming County; and at State College.

As shown in the figure, this experiment tests four methods of soil management, viz., clean tillage, tillage and cover crop, sod mulch, and sod. Each treatment occurs both without fertilization and with it. The stable manure is applied annually at the rate of 12 tons per acre; and the commercial fertilizer at the rate of 30 pounds of nitrogen (N), 60 pounds of phosphoric acid (P_2O_5), and 100 pounds of potash (K_2O).

On the mulch plot all herbage remains in the orchard, the first cutting being raked to the trees as mulch, and an additional mulch of old straw, swamp hay or buckwheat straw at the rate of about three tons per acre is applied annually. In this latter respect it differs from the so-called "Hitchings plan," and as a conserver of moisture it is undoubtedly very much better. On the sod plot, the first cutting of herbage is removed from the orchard and the second is left where it falls. The tillage plots are all cultivated until early in July, when those receiving the cover crop are seeded to crimson clover, hairy vetch or medium red clover and alsike, either singly or in combination.

The results to date, from the *unfertilized plots of the young orchards,* are shown in Table VII. These results and those in later tables on young orchards have been obtained by combining the results from three orchards, whose age as noted in Table II ranges from seven to sixteen years.

Table VII.

Effect of CULTURAL METHODS on YIELD, COLOR, SIZE and GROWTH, without Fertilization.

Expts. 217, 218, and 219. Young Orchards. (a) Yield.

1907-9	PLOT I Clean Tillage	PLOT IV Tillage and Cover Crop	PLOT VII Sod Mulch	PLOT X Sod
Totals, 3d year	15048 ℔	16057 ℔	17776 ℔	13880 ℔
Ratios	108.4	115.7	128.1	100
"	100	106.7	118.1	
"		100	110.7	
1909 (b) Color. % Apples Colored ½ or more.				
Average per cent	75.4	81	81.5	85.6
Ratios	100	107.4	108.1	113.5
1908-9. (c) Size. Average Weight of Apples.				
Average Weight	4.5 oz.	4.74 oz.	4.91 oz.	4.69 oz.
Ratios	100	105.3	109	104.2
"		100	103.6	
1907-9 (d) Growth. Increase in Trunk-girth.				
Average Increase	4.38 in.	4.14 in.	4.29 in.	3.58 in.
Ratios	122.3	115.6	119.8	100
"		100	103.6	

In these results, the mulch system is first in yield and size of apples, second to sod on color, and second to clean tillage by a slight margin on growth[1]. It has surpassed the cover-crop method on every phase and in total ranking is plainly first thus far in the combined results of this group of experiments. Reserving judgment on the relative merits of these systems for the present we shall turn to the data from a similar experiment in an older orchard,—that of Mr. Fassett, in which the trees are now 37 years old. The results from the unfertilized plots in this orchard are shown in Table VIII.

Table VIII.

Effect of CULTURAL METHODS on YIELD, COLOR, SIZE and GROWTH, without Fertilization.

Expt. 221. Mature Orchard. (a) Yield.

1907-9	PLOT IV Tillage and Cover Crop	PLOT VII Sod Mulch
Totals, 3 years	34269 ℔	23294 ℔
Ratios	147.1	100
1908-9. (b) Color. % Apples Colored ½ or more.		
Average % of Color	57.4 %	87.5 %
Ratios	100	152.4
1908-9 (c) Size. Average Weight of Apples.		
Average Weight	4.75 oz.	5.04 oz.
Ratios	100	106.1
1907-9 (d) Growth. Increase in Trunk-girth.		
Average Increase	2.9 in.	1.32 in.
Ratios	219.7	100

From the above results it will be noted that *in the mature orchard* tillage with a cover-crop for three years has been far superior to sod mulch in yield and growth, having borne nearly one and a half times as much fruit and showing more than double the increase in growth. In color, the mulched fruit excels by more than 30%[2]; and in average size of apples it excels by about 6%. This last fact is undoubtedly connected with the smaller crop on the mulched trees.

The results of tables VII and VIII are apparently contradictory. They are all explainable, however, on the bases of soil moisture and

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1. The margin is really slighter than appears in the table, as the 1909 measurements in the mulch plots of experiment 218 were taken a little higher on the trunks than those of 1907, owing to the presence of screens on the trees at the later date.

2. Really the mulch excels in color by 52.4 per cent., using the amount of color on the cover-crop area as a base.

age of trees. In the young orchards, with the herbage and three-ton addition of straw, an effective mulch of sufficient extent was maintained, while in the old orchard we were unable thus to cover more than probably half the roots. In the latter case the term *sod* mulch was distinctly appropriate since at least the outer half of the roots was under a typical sod and often in dust-dry condition.

The results in Table VII indicate that, even in trying seasons such as the last two have been, the moisture in orchard soils may be conserved at least as effectively by a good mulch as by tillage. This conclusion is corroborated by moisture determinations made by Shutt, of Ottawa, Canada, in 1905 and 1906[1]. He also has found that leguminous plants, particularly those of dense and matted growth like hairy vetch, are much less severe in their drain on soil moisture than the grasses; and that the shade of the growing vetch is a better moisture conserver than the mulch formed by cutting and leaving it in place. In other words, the loss by capillarity and surface evaporation from the practically bare ground was greater, under the conditions at Ottawa, than the transpiration through the legume[2]. The cover on our mature orchard is grass only, while on the young orchards a scattering growth either of alsike or medium red clover has been maintained in addition.

In further explanation of the difference in relative effectiveness of the sod-mulch and cover-crop in Tables VII and VIII, we may call attention to the hastening influence on bearing, which sod undoubtedly exerts under favorable conditions. This was shown in our results of last year[3], where sod on these same three orchards surpassed clean tillage in yield by 13%. It is also shown here later, especially in the sod-manure plot of Table X. But the fact that this sod influence can be easily overdone and made to disappear under unfavorable conditions, is clearly shown in our results from the unfertilized sod plots of Table VII.

The next table is introduced to show the *effect of adding fertilizers* to the four cultural methods. All unfertilized plots are excluded from this table, and the yields given include both the manured and commercially fertilized plots under each method.

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[1] Central Experimental Farm. Report of the Chemist, 1907, page 151.

[2] Ibid. 1904, page 158.

[3] Penn. Expt. Station Bulletin 91:15. 1909.

Table IX.

Influence of CULTURAL METHODS on YIELD, with Fertilization.

Expts. 217, 218, 219. Young Orchards.

	Plots 2 & 3 Clean Tillage	Plots 5 & 6 Tillage & Cover Crop	Plots 8 & 9 Sod Mulch	Plots 11 & 12 Sod
1908 Yields....	9193 ℔	9512 ℔	11203 ℔	10351 ℔
1909 Yields....	14554	12443	12571	12823
Totals.........	23747	21955	23774	23174
Ratios.........	108.2	100	108.3	105.6

Expt. 221. Mature Orchard.

	Plots 2 & 3 Clean Tillage	Plots 5 & 6 Tillage & Cover Crop	Plots 8 & 9 Sod Mulch	Plots 11 & 12 Sod
1908 Yields....		6684	10351	
1909 Yields....		28297	22545	
Totals.........		34981	32896	
Ratios.........		106.8	100	

As compared with tables VII and VIII, these results show a marked *leveling effect* from the addition of fertilizers. In other words, the applications of plant food have tended strongly to reduce or even nullify the differences due to cultural methods. This effect was also very distinct in the appearance of the trees in the field.

A *consecutive increase* in productiveness following the addition of plant food has been very marked in some cases. For example, the mulched plots of Experiment 221, receiving manure and commercial fertilizer, in 1907 produced 3050 pounds of fruit; in 1908, as seen in the table, they produced 10351 pounds; and in 1909, 22545 pounds. And this occurred on mature trees receiving no tillage.

Fertilization for Different Cultural Methods.

The question often arises as to what is the best form of fertilizer to accompany different cultural methods. This question is partially answered by the data in Table X.

Table X.

Effect of MANURES on YIELD.

Expts. 217, 218, 219.

Season 1908-9 (2nd and 3rd Year)	Unfertilized	Manure 12 T. per Acre	Com. Fertilizer 30-60-100 lb. per A
Clean Tillage	13698 ℔	21605 ℔	23022 ℔
Tillage and Covercrop	14550	20582	20681
Sod Mulch	15702	23678	20408
Sod	11706	24772	17929
Totals	55656	90637	82040
Ratios	100	162.8	147.4
“		110.5	100
Expt. 221.			
Tillage and Covercrop	33119	31924	35502
Sod Mulch	21091	35396	28370
Totals	54210	67320	63872
Ratios	100	124.2	117.8
“		105.4	100

This table shows the influence of manures[1] on yield when used in connection with different cultural methods. It will be observed that in every case except one, the yields from the fertilized plots have surpassed those from the unfertilized. And in the one exception the yields on the corresponding fertilized plots this past year were more than double the yield on it. In total effect, considering all treatments, the fertilized plots show a distinct increase over the unfertilized; and stable manure at the rates applied shows a small gain over the commercial[2].

Examining the data further, it appears that in every case on the tilled plots commercial fertilizer has surpassed manure while on the untilled plots the reverse is true. In other words, the present data indicate that from equal values of manure and a proper commercial fertilizer the best results are obtained by using the manure on sod or mulch areas, and reserving the fertilizer for use in connection with tillage. Either material, however, may be used satisfactorily and it is very probable that in any case a more or less regular alternation can be made more successful than the use of either alone.

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[1] Including complete commercial fertilizers under the term "Manure."

[2] More actual plant food is being applied in the manure, since twelve tons of average stable manure are estimated to contain about 120 lb. each of nitrogen and potash (K_2O), and about 80 lb. of phosphoric acid (P_2O_5). The relative cost per acre, as applied is about $15 for the manure and $13 for the commercial fertilizer.

Table XI.

Effect of MANURES on COLOR, SIZE and GROWTH.

A. Expts. 217, 218 and 219. (a) Color. % Apples Colored ½ or more.

	Unfertilized	Manure	Com. Fertilizer
Average % of Color	71.2 %	61.9 %	62.4 %
% Benefit		— 9.3	— 8.8
(b) Size. Average Weight of Apples.			
Average Weight	4.71 oz.	4.99 oz.	5.25 oz.
Ratios	100	106	111.5
		100	105.2
(c) Growth. Increase in Trunk-girth.			
Average Increase	4.12 in.	4.3 in.	4.43 in.
Ratios	100	104.1	107.5
		100	103
B. Expt. 221. 1908–9. (a) Color. % Apples Colored ½ or more.			
Average % of Color	72.5 %	68.1 %	73.5 %
% Benefit		—4.4	1.
(b) Size. Average Weight of Apples.			
Average Weight	4.89 oz.	5.42 oz.	5.33 oz.
Ratios	100	110.8	109
(c) Growth. Average Increase in Trunk-girth.			
Average Increase	4.22 in.	5.86 in.	4.92 in.
Ratios	100	139	116.6
"		119.1	100

Table XI shows the effect of manures in both young and old orchards on color and size of fruit and on growth of trees. The effects have been fairly distinct in all cases,—reducing the color with one exception, and apparently increasing the size of fruit and tree-growth[1]. In all cases, the color is least on the plots receiving stable manure. In the old orchard, manure shows some advantage over commercial fertilizer in wood growth and in size of apples, with effects reversed in the young orchards. The greater effect of commercial fertilizer in the young orchards is probably connected with the smaller area over which it is distributed, thus giving relatively stronger applications.

The above data are obtained from extensive work during a relatively short period. In Table XII, we have data from the reverse conditions,—one experiment continued over 21 years.

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[1] We say "apparently" increased the size of fruit since the matter of size is undoubtedly primarily dependent on soil moisture, foliage competition, freedom of sap-flow and number of fruits on the tree. Thus any fertilizer effect must necessarily be indirect, as in the case of color.

Table XII.

FERTILIZATION of APPLES in MASSACHUSETTS.

(Treatment and Total Yields per Acre from 1889 to 1910).

Annual Treatment	PLOT 1 Manure 10 Tons	PLOT 2 Wood Ashes 1 Ton	PLOT 3 Check	PLOT 4 Bone & K Cl 600 & 200	PLOT 5 Bone & Low G Sulfate 600 & 400 lb.
Ave. Girth..	38.25 in.	33.23 in.	27.98 in.	32.27 in.	37.02 in.
Ratios......	136.7	118.8	100	115.3	132.3
Yields, lb...	24934	12841	3940	14453	21863
Ratios......	632.8	325.9	100	366.8	554.9
Color & Size	4	1	5	3	2

These results are similar to those recorded in the preceding tables with the differences in some cases even more distinct. In every respect the treated plots have proved superior to the untreated. The manure plot, which alone receives nitrogen in quantity, leads in yield and growth but falls next to the check in quality. It is closely followed in yield and growth and much surpassed in quality by plot 5, which received ground bone and low grade sulfate of potash. The superiority of 5 over 4 which differs only in the carrier of the potash is very interesting. Whether it is due to the magnesia in the sulfate or to a harmful affect of the chlorine accumulating from the muriate, or to a soil difference, cannot yet be stated. It will be recalled that our results of the third year, Table III, corroborate it, in plots which compare only sulfate and muriate.

The practical point, however, is that with such differences as these existing, even though unexplained, the safer policy is to use potash in the sulfate form. The difference in cost is small, and if so desired it can be readily met by a reduction in the amount of potash applied. This would be justified by our present results, which indicate that the usual recommendations of this material for orchard use may be reduced to advantage.

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1. Data furnished by Director Wm. P. Brooks, of the Mass. Expt. Sta., December, 1909. This experiment has been running at the Massachusetts Station during the last 21 years. The trees were planted one year after the experiment was started and the plots contain three trees each of Baldwin, Rhode Island Greening, Roxbury and Gravenstein. The soil is a "moderately heavy, gravelly loam with a moderately compact (clay) subsoil," and is stated to have been "highly exhausted, chiefly by the production of hay, before the experiment started."

Effect of Different Fertilization on Foliage.

The beneficial effect of nitrogen on foliage is generally recognized. It is not so widely known, however, that this effect is often materially increased by the further addition of the other ingredients, phosphate and potash, and also that the latter constituents *in the absence of nitrogen applications* may exert a very marked influence. These facts are brought out in Figures 6, 7, 8, and 9, taken on October 20, 1909, and showing plots 4 to 9 of Experiment 220. All treatments have been in operation for three years.

The effect of nitrogen on foliage appears much sooner than that of the phosphate-potash combination. The effect of the former appeared very distinctly within two months after the first application. which was made on July 8, 1907[1], while with the latter materials the benefit scarcely became of importance until near the close of the third year.

Besides the quick response to nitrogen which occurred here, other interesting results appeared. These trees in 1907 effectively resisted a severe drought and an attack of "frog-eye" leaf-spot, which early defoliated the untreated trees. They also came out into leaf much greener again the following spring and showed as marked differences in late May of 1908, before the second application, as they had shown in the preceding autumn.

This indicates a marked winter-storage capacity in apple trees. And the whole experience with this July application undoubtedly has a bearing on the proper time for applying soluble, transient fertilizers to such perennial plants as apple trees. Coupled with the Woburn experience, it indicates the advisability of delaying such applications until the plant's supply of stored food is about exhausted and available food becomes a limiting factor. This delay, of course, is less urgent when nitrogen is applied in less soluble forms, such as stable manure, dried blood, and leguminous crops.

Some Practical Suggestions.

Bringing together the foregoing results and other observations to date, the following practical suggestions are offered:

Fertilizer for Apples in Pennsylvania.—No recommendation will fit all cases, but where a fertilizer is evidently needed, present results indicate the desirability of the following combination (in amounts per acre):

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[1] It was applied in the form of nitrate of soda as a top-dressing. It was left uncultivated because of the fact that parts of the experiment are so rough and stony as to render tillage impossible.

30 ℔. actual nitrogen (N),
60-75 ℔. actual phosphoric acid (P_2O_5),
50 ℔. actual potash (K_2O).

Such amounts of plant food are obtainable by mixing any one of the following combinations,—the mixing being done either at home or at the factory:

(a) 100 ℔. nitrate of soda (15½ % N),
100 ℔. dried blood (12½ % N),
250--300 ℔. steamed bone meal (24 % P_2O_5 & 1 % N),
100 ℔. sulfate of potash (50 % K_2O).
or (b) 100 ℔. nitrate of soda (15 % N),
120 ℔. dried blood (12½ % N),
400-500 ℔. acid phosphate (15 % P_2O_5),
100 ℔. sulfate of potash (50 % K_2O).
or (c) 500 ℔. of a 6-12-10 fertilizer.

The above amounts are for bearing trees of medium age. For younger trees they may often profitably be reduced by a third or more, with corresponding increase for older trees. The combination is offered as a beginning treatment for average conditions and is expected to be varied as later results direct. If sufficient nitrogen can be obtained in green cover crops, or in stable manure, it can well be reduced in amount here, preferably first omitting the dried blood. Annual applications of this fertilizer, alternated with stable manure at the rate of about 10 tons per acre at least every third or fourth year, will probably give best results.

With the nitrate present, the best time of application is probably somewhat after the blossoms fall. The manure may be applied any time during the winter or spring. Also it should be remembered that the effect of fertilizer is not apparent on the crop before the second year and possibly even later.

The area of distribution for fertilizers depends upon the position and extent of the feeding roots. These differ with the age, variety and kinds of soil. In the case of mature Northern Spy in a moderately sandy soil, we have followed the roots to a distance of nearly 47 feet from trees whose branches extended laterally but little over 15 feet. In such a case the fertilizer should of course be distributed over all the ground excepting near the trees. In most cases of well-established trees, however, it is probably sufficient to make the distribution in a circle beginning about three or four feet from the trunk and extending well out beyond the spread of the branches.

Where possible, it is doubtless best to cultivate the fertilizer into the soil as soon as practicable after application. Some of our best results, however, have been obtained without this, merely leaving it as a top-dressing. From our observation, the feeding roots are not so deep as commonly supposed, the great majority being within the surface foot and practically all within the surface two feet. Hence, even superficial applications are not so inaccessible as may be supposed.

Cultural Methods.—Where the tillage-and-cover-crop method is followed, it is considered best to do the plowing fairly early, at least by the middle of May[1], in order to avoid unnecessary cutting off of the season's absorbent roots. As soon as possible after the plowing, a surface mulch should be established and maintained by tillage as often as needed until early in July. At that time, about July 10 to 20, the cover crop should be sown, unless the moisture demands of the fruit make a later sowing advisable. Most leguminous cover crops[2] are best sown near the earlier date in order to insure sufficient growth before plowing, if turned under the following spring. Millet, oats and Canada peas are best near the latter date or even a week or so later, while rye (as a cover crop only) may be sown any time from late August to October.

By proper use of cover crops the fertility question can be greatly simplified, and much relief secured from frost and winter injuries as well. In the two latter cases, however, the procedure is just reversed. Thus winter-killing due to intense cold is avoided by securing complete and fairly early ripening of the wood, while injuries due to too early blossoming or incomplete dormancy are best reduced[3] by somewhat prolonging the season of growth or in other words by retarding the entrance to the dormant period.

The Mulch System.—Where tillage is impracticable, and sometimes where it is available, a proper mulch is often very satisfactory as indicated in our results. The chief values of this system may be summed up as follows. It avoids erosion on sloping ground; reduces labor; apparently hastens bearing in young trees; may assist in blight control; and effectually conserves moisture, if mulch is maintained sufficiently deep (about three or four inches at least). Its defects are: frequent high cost of sufficient materials for effective mulch; possible danger from mice and from fire; favorable hibernating quarters for injurious insects and fungi; and lack of flexibility in moisture control, the moisture being conserved as thoroughly in late fall, when not often wanted, as it is at any other time. Its successful use, therefore is likely to depend on age of trees, prevailing pests, relative cost of labor and of mulch materials and general moisture conditions of the orchard in which it is used.

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[1] Where moisture is abundant and the cover crops have not developed sufficiently the plowing may safely be deferred somewhat later than this.

[2] Among the best of these for annual use are crimson clover and soy beans. Hairy vetch, medium red, and mammoth clovers may be used either as annual or biennial covers; and hairy vetch, alsike and possibly sweet clover now seem to be promising as permanent covers in connection with a mulch.

[3] So far as this can be done by cover crops. Proper elevation with resulting air drainage is the chief means of reducing frost injury. (See work of Missouri Station.)

How Current Practice May Be Improved.

Finally, to increase their effectiveness, we urge all who are engaged in the production of fruit as a means of livelihood to adopt the experimental attitude and maintain some portions of their orchards for experimental work. It is self-evident that the best place to determine the crop-limiters of any particular orchard, and to develop and maintain a balanced treatment for it, is in the orchard itself. It is also evident that the surest method is to ask the trees.

This does not mean that one is to become the prey of every passing fancy which may be brought to his attention. But in most matters of importance in the management of an orchard there are one or more courses of action available, between which it is difficult to decide. After careful study of available evidence he should choose, for the orchard as a whole, the course that in general seems best. But in a small section of the orchard he should carefully try out the other possible courses, side by side with the one chosen. This should be continued long enough to determine for his particular orchard which course of action is really best.

This applies to methods or materials of fertilization, pruning, spraying, soil management, varieties, and indeed to nearly all the essential factors of fruit production. The ideas gained from a knowledge of the methods and results of others will be helpful in formulating the plans of experiment as well as in choosing the course for the orchard as a whole. Also, the orchardist can usually secure any help and advice from his State Experiment Station that may be needed to insure effectiveness of the test. Such a course cannot fail to be of the greatest value to commercial orchardists.

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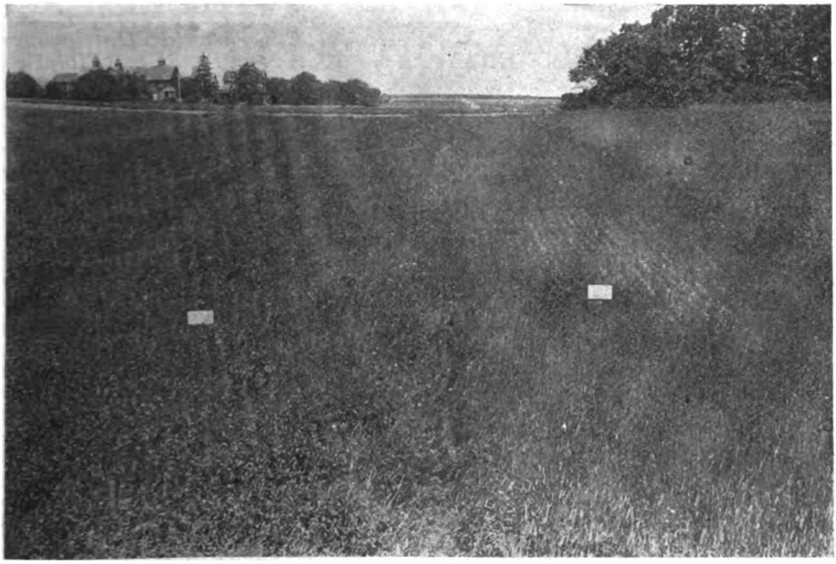
BULLETIN No. 101



MINERAL FERTILIZERS **NO TREATMENT**

MEADOWS AND PASTURES

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CENTRE COUNTY, PENNSYLVANIA
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*Absent on Leave.
†Assigned by the Bureau of Soils, U. S. Dept. of Agr.

The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 101

MEADOWS AND PASTURES*

BY

THOMAS F. HUNT

There is an old Flemish proverb, which reads as follows: No grass, no cattle; no cattle, no manure; no manure, no crops.

What these lowland farmers of Europe meant was that good grass is the basis of good agriculture. We are not without illustrations in this country, as, for example, the famous blue grass region of Kentucky. Every practical farmer knows that if he has a good, heavy sod to plow up he may reasonably expect, other things being equal, to secure a good crop of corn, while if his meadow is allowed to run out the chance of successful crop is very much lessened.

It has been the custom to apply yard manure to land for corn and to use commercial fertilizers for wheat, but the value of the fertilizers, particularly commercial fertilizers, in increasing the growth of grass and thereby building up the fertility of the soil has not been generally understood. It is true that some farmers do top dress their meadows with yard manure and this is a good practice but very few have applied commercial fertilizers to their grass lands. After some years of investigation of this subject I believe it safe to assert that the same money used in applying commercial fertilizers to grass lands will bring a greater profit than when applied for corn or wheat. Of more importance, however, is the fact that while obtaining this greater profit the land is made more productive for succeeding crops. This does not mean that fertilizers may not be used to advantage for either corn or wheat, but merely that a still greater profit results when applied to grass lands.

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* Address delivered on January 26th, 1910, before the Pennsylvania State Board of Agriculture, Harrisburg, and on February 3rd, 1910, before the Pennsylvania Live Stock Breeders Association, Philadelphia.

This paper has only one purpose. It is to demonstrate so clearly and forcibly that the above statements are true that land owners will be induced to act upon them.

In the address on "Soil Fertility" delivered before the last meeting of the Pennsylvania State Board of Agriculture, the speaker touched briefly upon the importance of clover in keeping up the fertility of the soil.* It is desired to develop a little more in detail the lesson of these fertilizer experiments at the Pennsylvania Station with reference to the influence of common red clover. Those who listened to the address of last year or who have read the bulletins of the Pennsylvania Station know that these fertilizer experiments which have been in progress twenty-eight years consist of four tiers, each containing thirty-six eighth acre plats. The four tiers represent a complete four year rotation of corn, oats, wheat and hay (clover and timothy). The fertilizers are applied to the corn and wheat only thus being applied on alternate years or twice in the rotation.

It so happens that there are five plats on each tier receiving no fertilizers of any sort while there are four which have received only mineral fertilizers consisting of 48 pounds phosphoric acid equivalent to 320 pounds of 15 per cent. dissolved bone black or dissolved rock phosphate and 100 pounds of potash equivalent to 200 pounds of muriate of potash, 80 per cent. purity. The following table shows the average yield of the seven products of the rotation during the last five years of the first twenty-five years, where there was no fertilizer and where mineral fertilizers were applied. These years have been chosen because the conditions probably more nearly represent the comparative results to be obtained on run down limestone soil.

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* See Pennsylvania Sta. Bul. No. 90 (1909).

Effect of Mineral Fertilizers at the Pennsylvania Agricultural Experiment Station. Average 5 Years, 1902-6.

	No treatment 5 plats	Phosphoric acid 48. Potash 100 4 plats
Corn, ears, bu	35.6	51.4
Corn, stover, lb.	1711	2685
Oats, grain, bu.	23.4	34.4
Oats, straw, lb.	1110	1693
Wheat, grain, bu.	10.5	19.9
Wheat, straw, lb.	816	1627
Hay, lb.	2329	4469

During the last five years, 1902-1906, in place of 36 bushels of corn where no fertilizer was applied 51 bushels were grown where mineral fertilizers only were used. There were 34 bushels of oats in

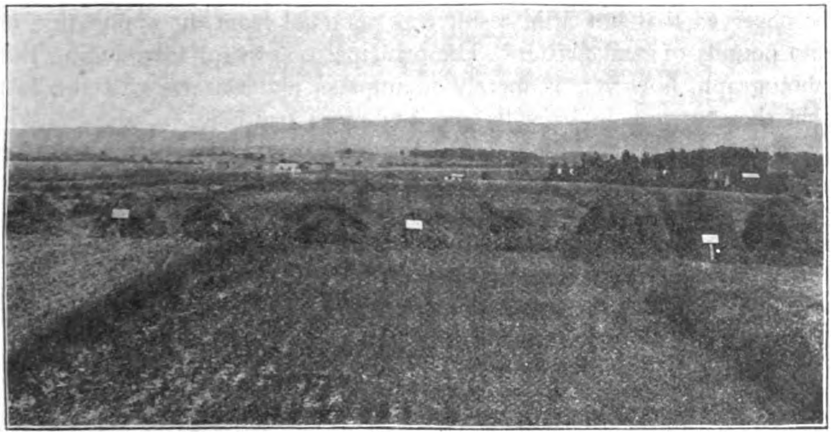

Fig. 1

	PLAT 13	PLAT 14	PLAT 15
Treatment—	Plaster, 320 lb.	Nothing	Acid phosphate, 320 lb. Muriate of potash, 100 lb.
Yield of hay (1909)—	1408 lb.	1216 lb.	4496 lb.

Fig. 1 shows the effect of mineral fertilizers in keeping up the fertility of the soil, in a rotation in which clover appears once in four years. In effect plat 15 represents a farm in which one-half the area received each year 320 pounds acid phosphate and 100 pounds muriate of potash and all crops sold. See table above.

place of 23 bushels, 20 bushels of wheat in place of 10½, and nearly 2¼ tons of hay in place of a little more than a ton. This was done at an annual cost of $3.20 per year, but if we are correct in believing that the application of potash was excessive and could be reduced one-half, then the result would be obtained at an annual cost for fertilizer of $2.20.

The photograph, (Fig 1) shows the hay raised this year 1909 on plats 13, 14 and 15 of Tier 3. Below is shown the treatment as follows:

	Treatment.	Yield per acre.
Plat 13	Plaster, 320 lb.	1408
Plat 14	No treatment	1216
Plat 15	P 48 K 100	4496

Plat 14 has received no fertilizer in twenty-eight years, while plat 15 has received the mineral fertilizers every other year. The first plat yielded at the rate of a little over three-fifths of a ton of hay, while the latter produced at the rate of nearly 2¼ tons per acre. It will also be observed that but little result was obtained from the application of 320 pounds of land plaster. The principal reason for introducing this photograph, however, is merely to impress my hearers with the fact that these were actual results obtained from real land.

The purpose of calling attention sharply to the results obtained from the use of these mineral fertilizers, phosphoric acid and potash, is not to point out their value in keeping up the fertility of the soil so much as it is to call attention to the vast importance of clover and other leguminous crops in supplying the nitrogen. Nitrogen is absolutely necessary to growing crops. It usually is the first element to be exhausted from the soil. It is the most expensive element to replace, costing about 20 cents a pound as compared to five cents for phosphoric acid and four cents for potash.

The three principal methods of keeping up the nitrogen supply of the soil open to the average farmer are (1) by raising clover or other leguminus crops, (2) by carefully saving through the use of proper bedding the liquid excrement by animals, since it is the liquid excrement that contains most of the nitrogen, and (3) by buying nitrogen in commercial fertilizers at twenty cents a pound for the nitrogen contained. All three ways are good in their place. It is safe to say, however, that the farmer who raises staple farm crops and does not have a systematic rotation in which clover or some other leguminous crop enters is slowly going into bankruptcy.

But, it may be said, I cannot raise clover any more. It must be admitted that there is a vast area, more than ten million acres in New York, Pennsylvania and Ohio known as the Volusia series of soils on which in recent years great difficulty has been found in raising red clover. The distribution of this series of soils is shown roughly on the map shown in Fig. 2. It so happenes that the speaker lived for

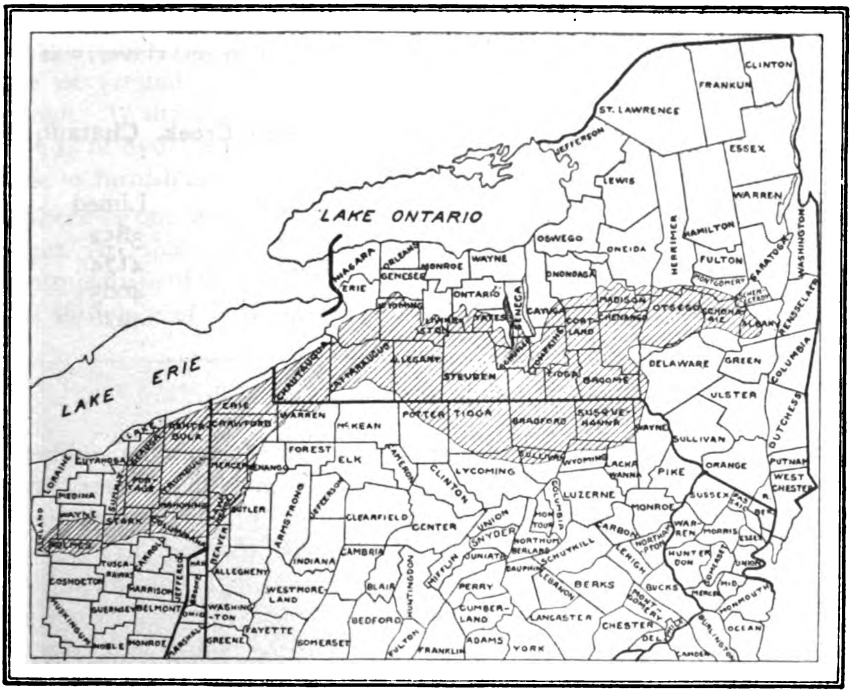

Fig. 2

Fig. 2—Sketch map showing the region occupied by Volusia soil in Ohio, Pennsylvania, and New York. [U. S. Dept of Agr. Bu. of Soil, Bul. No. 60.]

some years on the edge of this area and studied the soil conditions with considerable care. Some experiments were planned and carried out by Cornell Station in order to determine, if possible, why clover failed so completely on certain of these soil types, especially that type known as the Volusia silt loam*.

A careful study of all the probable factors influencing the growth of red clover was made. Among other things experiments were made to determine the influence of lime, yard manure and commercial fertilizer in producing red clover. One of these trials was conducted on a loam soil at Cherry Creek, Chatauqua county, New York, described as a once fertile farm that had become so poor that the former owner had lost it. The following table shows the method of treatment and the results obtained during 1908. The mammoth clover was sown in oats the previous year. To avoid misunderstanding it should be stated that other results, not given here, indicated that common red clover was to be preferred to mammoth clover.

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* New York Cornell Sta. Bul. No. 264 (1909); Experiments in the growth of clover on farms where it once grew but now fails.

Yield of Mammoth Clover in 1908 at Cherry Creek, Chatauqua County, N. Y.

No. plats	Treatment	Unlimed	Limed
5	Nothing	1824	3852
1	P, K	2349	4174
1	P, K, N	2235	4085
1	15 tons manure	2091	4976

P=Acid phosphate, 100 lb.
K=Muriate of potash, 50 lb.
N=Nitrate of soda, 100 lb.

Here the most important result was obtained by liming and here the best results were obtained by both manure and lime. Where there was a combination of manure and lime 2½ tons of hay were obtained in place of a ton without treatment. Not only was the yield of hay increased but the character was changed. Although only mammoth clover was sown, on the unlimed plats the principal grass grown with the clover was redtop, while on the limed plats the redtop was replaced in part by timothy which made a strong growth.

In another experiment made in Tompkins county where the soil type, Volusia silt loam, was less productive yard manure gave much less favorable results. The unlimed and unfertilized area yielded 1015 pounds of hay; the limed area which received mineral fertilizers yielded 1929 pounds of hay; while the limed area whch received yard manure yielded only 1555 pounds of hay. Where the land was unlimed the plat receiving mineral fertilizers yielded 1372 pounds while a similar plat receiving stable manure yielded 1246 pounds of hay. This second experiment, however, in no way detracts from the lesson to be derived from the Chatauqua county experiment. It merey shows that other conditions existed to prevent the manure becoming effective. In this particular instance it was probably due to the manure emphasizing the effect of the severe drouth.

Any land, which when sown to clover and timothy, produces in their stead chieflly redtop and sorrel (*Rumex acetossela*), will be benefitted by the use of lime. Apply anywhere from 1,000 to 4,000 pounds or from 15 to 50 bushels. In the opinion of the speaker it does not matter greatly how much is applied, when it is applied, or what kind is applied. The chief thing is to get finely divided lime into the soil Ordinarily it may be applied on top of plowed land when it is being prepared for corn. One may buy recently burned quicklime and allow it to slake in piles, or buy slaked, (hydrated) lime or ground (pulverized) limestone provided it is ground finely enough. It should be remembered, however, that it takes about 1350 pounds of hydrated lime and about 1800 pounds of pulverized limestone to furnish as much actual lime as 1000 pounds of pure quick lime.

There is one lesson, however, that every land owner should not forget, viz., that while lime with manure will increase the yield the continued use of lime without manure may decrease it. Lime cannot take the place of fertilizers nor can fertilizers take the place of lime.

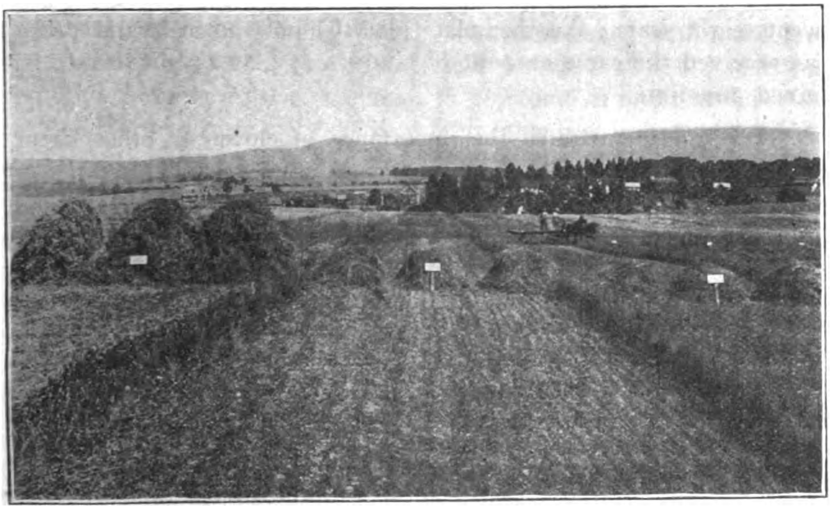

Fig. 3

	PLAT 22	PLAT 23	PLAT 24
Treatment—	Yard manure 6 tons Lime, 2 tons	Lime, 2 tons	Nothing
Yield of hay (1909)—	5784 lb.	1880 lb.	1040 lb.

Fig. 3, Plat 16, receiving 6 tons of manure but no lime yielded 4008 pounds of hay, thus showing that lime cannot take the place of manure and that the best results may not be obtained from manure without the use of lime.

The photograph (Fig. 3) of three plats shows the yield of timothy and clover from tier 3 of our fertilizer series in 1909. The yields of four plats are shown in table below:

The Effect of Manure and Lime at the Pennsylvania Agricultural Experiment Station.

No. Plat	Treatment	Yield of Hay 1909—lb.	Yield All Products 1882-1906
22	Manure, 6 tons, Lime 2 tons	5784	18016
23	Lime, 2 tons	1880	11632
24	No treatment	1040	11663
16	Manure, 6 tons	4008	17383

Plat 22 has had six tons of manure once in two years and two tons of quck lime once in four years.

Plat 23 has received the lime the same as plat 22, but has not been manured, while plat 24 has had nothing done to it during the past twenty-eight years. Another plat (plat 16) not shown in this picture has received the same amount of manure as plat 23 but has not received any lime.

Having demonstrated the importance of clover or other legume in maintaining the supply of nitrogen and having emphasized the importance of lime where needed to maintain a good stand of clover the next step is to demonstrate the importance of commercial fertilizers in maintaining and increasing the yield of meadows. In 1903 the Cornell Station began the study of timothy from a great variety of standpoints. Among the experiments started was one to determine the influence of fertilizers in increasing the yield of pure timothy hay. A piece of well worn but not exceedingly infertile land known as Dunkirk clay was used. It was the intention to seed the timothy in 1903 with wheat. The land was prepared and fertilized that fall but rains set in and prevented sowing the wheat. Oats and timothy were, therefore, sown in the spring of 1904. The table shows the actual average yield per acre of timothy hay obtained from the different plats during 1905, 1906 and 1907.

Average Actual Yield of Timothy Hay per Acre During 1905, 1906 and 1907 at the Cornell Agricultural Experiment Station.

No. of Plats	Treatment	Weight, lb.
8	Nothing	2901
1	P	4233
1	K	4490
1	N	4530
1	P, N	4797
1	P, K	4127
1	K, N	5127
6	N, P, K	6615
1	10 tons manure	5093
1	20 tons manure	7293

Commercial fertilizers were applied in the fall of 1903 as previously stated and directly to the timothy in the spring of 1905, 1906 and 1907 just as the grass was starting. Stable manure, however, was applied only in the fall of 1903 and in the fall of 1906. In the latter case, of course, as a top dressing. The average of eight nothing plats during three years shows a yield of timothy hay of about 1½ tons. The yield obtained from plats treated with commercial fertilizers varied from two to over three tons per acre, while the plats receiving yard manure varied from 2½ to 3½ tons. In order to show the effect of the fertilizers more distinctly this table has been prepared.

Timothy Hay on Dunkirk Clay at Cornell University Average Results 1905, 1906, 1907.

	Apparent increase in yield, lb.	Net annual gain due to fertilizers 4 years
N	1211	$1.71
P	682	1.13
K	988	2.03
N, P	1614	1.91
N,K	2082	4.55
P, K	1079	1.85
N, P, K	2632	5.46
10 tons manure	2975	9.37
20 tons manure	5175	14.60

N=160 lbs. nitrate of soda
P=320 lbs. acid phosphate
K= 80 lbs. muriate of potash

Note that N stands for 160 pounds of nitrate of soda equal to 25 pounds of nitrogen, P for 320 qounds of acid phosphate equal to 50 pounds of phosphoric acid, and K for 80 pounds of muriate of potash equal to 40 pounds of potash*. The manure has been estimated in this table at one dollar a ton or load. The first column shows the apparent increase in yield due to the treatment, that is to say, it shows how much greater the yield was than on adjacent unfertilized plats.

The yield of oats in the year 1904 is not shown in this table. While the fertilizers caused an increase in the yield of oats, the increase was not sufficient to pay for the fertilizers. In preparing the second column, therefore, in order not to over estimate the value of the fertilizers the loss from the use of them when applied to the oats has been subtracted. It is evident from this table that nitrogen was the most important element in increasing the growth of timothy on the soil in question, and that next to that potash caused the greatest gain in weight. However, as is usually the case a complete fertilizer gave a larger yield than any two elements. Counting yard manure worth one dollar a ton the great value of stable manure is shown in producing timothy. The value of the manure may be stated in another form. Neglecting entirely the increased yield of oats due to the application of manure and estimating timothy hay at $10 a ton the manure was worth $2.18 a ton or load when ten tons were applied, and $1.94 when twenty tons were applied. As the experiment progresses the smaller application of manure becomes relatively more valuable per ton of manure applied. In general terms a ton or load of manure produced about two dollars worth of hay when the latter is worth $10 per ton.

This experiment emphasizes the readiness with which timothy responds to fertilizers of any kind in this humid climate. Almost any good tillable land in Pennsylvania can be made to yield from two to three tons of hay per acre in an ordinary season. In 1908 the Pennsylvania Experiment Station weighed twenty-four tons of well cured hay from 5 2-3 acres. The previous year certain portions of this same area yielded at the rate of 5 tons and 189 pounds of hay per acre, although the weight of the whole field was not determined in that year. In 1908 the Experiment Station had two fields in timothy and clover. From one field of nine acres 42 loads of hay were obtained, while from another field of exactly the same soil type eight loads of hay were obtained from twenty acres. The first had been well farmed, the second had not.

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* The critical reader will observe that the increased yield of hay in the N P K plat (complete commercial fertilizer) does not correspond to the total yield of hay on the complete commercial fertilizer plats as shown in the preceding table. This is because it was deemed best by the writer to point out the plat which appeared to have received the most favorable combination of ingredients. Complete data may be obtained from New York Cornell Sta. Bul. No. 261 (1908).

The whole story of the timothy meadow experiment has not been told. The most important part of the story is yet to follow. The purpose of this experiment was not primarily to determine the direct value of commercial fertilizers in increasing the yield of timothy hay but to determine whether the fundamental principle underlying the old Flemish proverb was sound, namely, that good grass is essential to a good agriculture.

After these plats were in timothy for three years they were plowed up and planted to corn without the addition of any fertilizer whatever in order to determine the residual effect of the fertilizers on the subsequent crop. These results have not yet been published but Professor J. A. Bizzell of the Cornell Experiment Station has furnished me the detailed results in which it is shown that the eight plats which during the previous year had received no fertilizer gave an average yield of 30.4 bushels of corn per acre, while the six plats which had received a complete commercial fertilizer gave an average yield of 56.8 bushels or a gain of 26.4 bushels, while the two plats which twice in the previous four years had had two applications of stable manure gave an average yield of 67½ bushels, or a gain of 37.1 bushels per acre*. A handsome profit had already been made from the use of commercial fertilizer and the stable manure. The gains, therefore, represent almost clear profit since the only additional cost was that of harvesting the increased yield. This is taking no account of the increased yield of stover which was nearly, although not quite, as marked as that of the grain.

Even to the hardened investigator these results come almost as a revelation. It is all so simple. All that was done was to apply broadcast by hand at the right time from one-tenth to one-fifth of an ounce per square foot a commercial fertilizer containing the proper proportion of nitrogen, phosphoric acid and potash. If, however, the results which have been given are to be duplicated the greatest care must be taken to have the conditions and methods correct. To obtain the best results three things are essential: (1) there must be a proper stand of grass, (2) the fertilizers must be applied at the right time, (3) the fertilizers must be of the proper character.

One reason why good results are obtained by the use of commercial fertilizers on grass land is due to the fact that there are so many plants to the acre and that the soil is so full of plant roots ready to make the fullest use of fertilizers applied. It is highly important also that the plants growing upon the land shall be the right kinds. Not only will the wrong plants or weeds reduce the quality of hay but they usually reduce the yield because generally they will not produce the same weight as would the timothy or clover which they displace. Where, therefore, the meadows have run out and a poor stand of grass remains, the land should be plowed, limed if needed, and put into a systematic rotation. There will then be a stand of grass that it pays to maintain by the use of commercial fertilizers. As an illustration a trial made at the Pennsylvania Station during 1909 may be mentioned.

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* Since the above was written the results of this experiment have been published in New York Cornell Sta. Bul. No. 273 by Lyon and Morgan. Copies may be obtained by addressing New York State College of Agriculture, Cornell University, Ithaca, New York.

The Pennsylvania State College has recently added a run down farm of 200 acres to its holdings. A certain twenty acre field which was in wheat when purchased was this year in grass, mostly timothy. The land was too poor to obtain a good catch of clover, although an abundance of seed was sown. Even the timothy was a poor stand. From 11.7 acres of this plat six loads of hay were obtained. These loads were not weighed but if we estimated them at 1700 pounds each 875 pounds of hay per acre is obtained. On the remaining 8½ acres on April 5, 1909, just as the grass began to grow commercial fertilizers were applied at the following rate per acre: Acid phosphate 150 pounds, muriate of potash 50 pounds, sodium nitrate 150 pounds. From this 8½ acres eleven loads of hay were obtained while from the 11.7 acres unfertilized but six loads were obtained. If the loads are again estimated at 1700 pounds per acre the yield in place of being 875 pounds per acre was 2200 pounds per acre. The cost of the fertilizer not including the cost of application was $5.57 per acre or about $8.40 per ton of hay. While this is a fairly satisfactory result it is not what it should have been because of the poor stand of grass.

The second important consideration is the time of application of the fertilizer. It is very important that the commercial fertilizer should be applied just when the grass begins to start in the spring. The station is of the opinion that a delay of even a week at this time may seriously interfere with the effectiveness of the fertilizer. In order to get the best yield of hay it is essential to get a good, strong growth during the cool, moist portions of the season. It is during this time that we have the least soluble nitrates in the soil and hence doubtless the nitrate of soda supplies the necessary nitrogen in the right form for the plants.

Third, in order to get the best results with commercial fertilizers on grass lands, it is necessary to apply a commercial fertilizer containing the right proportion of nitrogen, phosphoric acid and potash. No absolute rule can be laid down for all lands and conditions, but for average conditions the application to grass lands of 25 pounds each of nitrogen, phosphoric acid and potash is recommended. This may be obtained by applying 350 pounds of a 7-7-7 mixed fertilizer or by applying a mixture composed of 150 pounds of nitrate of soda, 150 pounds of acid phosphate and 50 pounds of muriate of potash. It will be noticed that the ordinary mixed fertilizer commonly used for wheat and corn is relatively too high in phosphoric acid and too low in nitrogen.

There is time for only a word about pastures. While quantitative results have not been obtained it has been abundantly shown that pastures may be improved by the application of either natural or commercial fertilizers. Where pastures are heavily grazed and the animals fed little or no other food, usually they gradually decline. If, however, the cattle are fed considerable concentrated food, especially of a highly nitrogenous character, or if the pastures are top dressed with manure or commercial fertilizers they may steadily grow better. An occasional application of seed, the clipping of the weeds and the harrowing of the fields will also contribute to this end.

The one lesson above all others that the Pennsylvania Station desires to teach, is that the soil cannot be made fertile economically at a single stroke, and that land can only be kept up to its highest productive capacity by a carefully and wisely ordered system of cropping, cultivation and fertilization.

In the address made a year ago the speaker suggested as a means to that end a five-course rotation that might meet the needs of many farmers. The rotation recommended was corn, oats, wheat, each one year, and timothy and clover two years. On a limestone soil the following fertilization was suggested: For corn, six tons of manure per acre; for oats, no fertilizers except when beginning to build up the soil, in which case 150 pounds of acid phosphate was recommended. For the wheat apply 350 pounds of acid phosphate and 100 pounds of muriate of potash. No fertilizer was recommended for the first crop of hay, for the second crop an application of six tons of yard manure applied the previous summer or fall and if yard manure is not available the application in the spring just as the grass begins to start of a commercial fertilizer just recommended for grass lands.

Another rotation is here suggested, not because it is any better than the one previously recommended but merely to show the possibilities of building up the soil through the application of commercial fertilizers to grass lands.

A SEVEN COURSE ROTATION.

Year	Crop	Fertilizer	Amount
1	Corn	Yard manure	6 tons
2	Corn	Yard manure	6 tons
3	Oats	Nothing.	
4	Wheat	Acid phosphate Muriate of potash	350 pounds 100 pounds
5	Clover and timothy	Nothing.	
6	Timothy	Nitrate of soda Acid phosphate Muriate of potash	150 pounds 150 pounds 50 pounds
7	Timothy	Nitrate of soda Acid phosphate Muriate of potash	150 pounds 150 pounds 50 pounds

Modifications of this rotation will occur to every practical farmer. The purpose here is to indicate the application of our present knowledge of the means of maintaining soil fertility to actual farming conditions and to emphasize the importance of some system if the best results are to be obtained.

William ullock

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 102

METHODS OF FATTENING STEERS

Concentrated and Bulky Rations Compared
Heavy and Light Rations of Corn Silage Compared
The Value of Shelter for Silage-Fed Cattle

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
SEPTEMBER, 1910

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 102

METHODS OF FATTENING STEERS

Concentrated and Bulky Rations Compared
Heavy and Light Rations of Corn Silage Compared
The Value of Shelter for Silage-Fed Cattle

By W. A. COCHEL and S. W. DOTY

Profitable feeding of beef cattle is possible only in sections where there is a large production of crops in proportion to the labor employed. Under average conditions it requires no more labor to feed the crops grown on the farm to beef cattle than to deliver them to the market. The same help, utilized in growing the crops in the summer, can feed them to the cattle in the winter, thus giving continuous employment throughout the year.

The character of the crops produced should determine the method of feeding in order that there may be as little cash outlay as possible in finishing cattle. Supplemental feeds should be purchased that will correct the deficiencies of home-grown feeds, increase their palatability and insure cheaper and more rapid gains as well as high finish on the cattle. In other words, beef cattle should be considered as machines for utilizing large amounts of roughage, such as stover, straw and damaged hay which would otherwise have little market value. These should be supplemented with concentrated and marketable feeds in such quantities as to make the cattle attractive to buyers. If the cattle under these conditions sell for a sufficient price to pay for themselves and market prices of feeds consumed, the feeder has, in addition to the profit from growing crops, a large amount of manure with which to maintain the fertility of the soil and increase the yield of crops.

During the winter of 1909-10 the Pennsylvania State College and Experiment Station has followed its usual practice of feeding a sufficient number of cattle to consume the stover, corn silage and hay and utilize the straw produced on the College Farm in the customary four course rotation. A limited amount of cottonseed meal was purchased in order to improve the farm-grown feeds. In addition to the cattle kept for instructional work, forty-eight head of steers were purchased upon the open market at the Union Stock Yards, Chicago, Illinois, December 1, 1909, to be used for experimental purposes.

Description of Cattle.

These steers were two-year-old grade Herefords and Shorthorns, averaging approximately 825 pounds per head, costing $4.65 per cwt. They were blocky, deep-bodied cattle of good quality, but lacking the weight, flesh, and breeding necessary to bring the best price as "feeders." They were shipped to State College immediately after purchase where they were fed shredded stover, mixed hay and corn silage until they had recovered from shipment.

Method of Experimentation.

For experimental purposes they were divided into four lots as nearly equal as possible in age, type, breeding, quality, condition and weight and fed as follows:

Lot I. Full feed grain, one-half feed corn silage and roughage according to appetite. (Fed in barn).

Lot II. Two-thirds feed grain, full feed of corn silage and roughage according to appetite. (Fed in barn).

Lot III. Full feed of grain, full feed of corn silage and roughage according to appetite. (Fed in barn).

Lot IV. Full feed of grain, full feed of corn silage and roughage according to appetite. (Fed in open shed).

These methods of feeding permit of comparisons between Lot I, fed a concentrated ration, and Lot II, fed a much more bulky ration, in which the proportion of digestible nutriments to dry matter is much larger; between Lot I, fed a concentrated ration with a limited amount of corn silage, and Lot III, fed a concentrated ration with a large amount of corn silage; and between Lots III and IV, both given the same ration, Lot III being fed in barn, and Lot IV, in an open shed.

Weighing, Bedding and Feeding.

Each steer was weighed individually for three consecutive days at the beginning of the test and again at the close. Water was shut off at five o'clock in the evening before the weights were taken at nine o'clock the following morning. The average of the first three weights was considered the initial,—of the last three, the final weights for the experiment. They were weighed individually under the same conditions at the end of each twenty-eight day period and collectively at the end of each fourteen day period in order to secure evidence upon their behavior throughout the test.

All lots were bedded at irregular intervals as the condition of the enclosures in which they were kept demanded. It was the intention that they should have a dry bed at all times. Water from the College supply was kept before them in abundance, except the nights before the weight was to be made. Coarse barrel salt was supplied in unlimited quantities at all times. Grain was fed at six o'clock in the morning, followed by silage as soon as the grain was cleaned up and again in the afternoon at four o'clock, followed by shredded stover or mixed hay.

Broken-ear corn was fed during the first two months when the steers began to shell off the corn, leaving a few cobs in the troughs. At this time a change was gradually made to shelled corn which was used until the close of the test. After the corn was fed, cottonseed meal was poured over it in order that each steer should get a proportional amount. Lots I, II and III were allowed to run loose in large box stalls in the basement of the College barn; Lot IV, in an open shed 12x30 feet, with access to a lot 30x70 feet. None of the steers were tied and every precaution was used to give them freedom.

Feeds Used.

The ear corn used was purchased locally. It contained a very high percentage of moisture and was at times slightly frozen. The shelled corn was shipped from Indiana and also contained a high percentage of moisture. It was comparatively free from rotten grains and dirt and, with the exception of one week, free from mould. The cottonseed meal was of excellent quality. The shredded stover was very poor, a large part of it having been struck by hailstorm late in the season and all of it damaged very materially by being stored in the barn in bad condition. The corn silage was of fair quality, showing some mouldy spots which could not be separated from that which was sound without excessive waste. It carried a relatively high percentage of moisture. The mixed hay was approximately one-half clover and one-half timothy with a slight sprinkling of other grasses. It was well cured and free from dust, mould and weeds.

Table I.

SHOWING AVERAGE PERCENTAGE OF AIR-DRY MATTER IN FEEDS FED AND REFUSED.

	Moisture	Air-Dry Matter
Ear Corn (20% cob)	22.9%	77.1%
Shelled Corn	16.69	83.31
Cottonseed Meal	6.14	93.86
Shredded Stover (Fed)	20.23	79.77
Shredded Stover (Refused) Lot I	24.87	75.13
Shredded Stover (Refused) Lot II	30.45	69.55
Shredded Stover (Refused) Lot III	25.72	74.28
Shredded Stover (Refused) Lot IV	23.50	76.50
Corn Silage	71.17	28.83
Mixed Hay	13.63	86.37

A sample of each feed, except silage, was carefully taken when weighed and held in closely covered lard cans until the end of each two weeks' period, when it was taken to the laboratory for analysis. The silage sample was secured at the end of each period and taken directly to the laboratory. Table I gives the average amount of moisture and air-dry matter determined for all samples. It shows that the corn and silage are higher while the stover and cottonseed meal are lower in moisture than is usually found.

Table II shows the average amount of feed consumed per head daily in each of the four lots. It may be noted that the average amount of dry matter consumed each month increases gradually from the beginning to the end of the feeding period. During the first month the grain was increased from six pounds per head daily at the beginning to fifteen pounds at the close: afterwards the rate of increase was much less rapid until the end of the third month when all lots were consuming the maximum amount of grain allowed them. They were fed at all times so that they would consume their grain ration in one-half hour and their

Table II.

SHOWING AVERAGE AMOUNT OF FEED CONSUMED DAILY PER HEAD BY MONTHS.

1st Month	Lot I.	Lot II.	Lot III.	Lot IV.
Ear Corn	8.84 lbs.	6.766 lbs.	9.018 lbs.	9.018 lbs.
Cottonseed Meal	1.476 “	1.803 “	1.116 “	1.116 “
Shredded Stover	5.39 “	3.689 “	4.372 “	3.973 “
Corn Silage	6.964 “	13.107 “	13.178 “	13.178 “
Mixed Hay	2.446 “	2.392 “	2.434 “	2.452 “
Air-dry matter per head daily	16.66 “	15.59 “	17.508 “	17.151 “
2nd Month				
Ear Corn	14.732 lbs.	9.821 lbs.	14.732 lbs.	14.732 lbs.
Cottonseed Meal	1.964 “	2.222 “	1.964 “	1.964 “
Shredded Stover	7.232 “	4.053 “	2.94 “	2.762 “
Corn Silage	10.00 “	20.00 “	20.00 “	20.00 “
Air-dry matter per head daily	21.94 “	18.85 “	21.45 “	21.25 “
3rd Month				
Ear Corn	1.666 lbs.	.595 lbs.	1.666 lbs.	1.666 lbs.
Shelled Corn	12.467 “	8.833 “	12.467 “	12.467 “
Cottonseed Meal	2.00 “	2.25 “	2.00 “	2.00 “
Shredded Stover	8.446 “	5.02 “	3.473 “	3.256 “
Corn Silage	9.166 “	18.333 “	18.333 “	18.333 “
Air-dry matter per head daily	23.005 “	19.36 “	21.69 “	21.49 “
4th Month				
Shelled Corn	17.535 lbs.	11.66 lbs.	17.535 lbs.	17.535 lbs
Cottonseed Meal	2.00 “	2.25 “	2.00 “	2.00 “
Shredded Stover	2.776 “	2.017 “	.919 “	.895 “
Mixed Hay	4.738 “	3.291 “	2.306 “	2.672 “
Corn Silage	8.333 “	16.666 “	16.666 “	16.666 “
Air-dry matter per head daily	25.22 “	21.14 “	24.05 “	24.33 “
5th Month				
Shelled Corn	18.00 lbs.	12.00 lbs.	18.00 lbs.	18.00 lbs.
Cottonseed Meal	2.00 “	2.25 “	2.00 “	2.00 “
Corn Silage	8.333 “	16.666 “	16.666 “	16.666 “
Mixed Hay	7.226 “	6.589 “	3.833 “	4.262 “
Air-dry matter per head daily	25.501 “	22.62 “	24.98 “	25.36 “

roughage in one hour. The maximum amount of concentrated feed used was twenty pounds per head daily, and the same of silage. As the grain rations were increased the silage and other roughage were decreased in order to reduce the paunchiness and increase the killing qualities of the cattle at the close of the experiment.

Table III.

SHOWING AVERAGE DAILY GAIN PER HEAD BY MONTHS.

Method of Feeding	**Lot I—12 Steers** Full feed grain, ½ feed silage and roughage according to appetite (in barn)	**Lot II—12 Steers** ⅔ feed grain, full feed silage and roughage according to appetite (in barn)	**Lot III—12 Steers** Full feed grain, full feed silage and roughage according to appetite (in barn)	**Lot IV—12 Steers** Full feed grain, full feed silage and roughage according to appetite (open shed)
1st Month	2.507 lbs.	2.395 lbs.	2.575 lbs.	2.46 lbs.
2nd "	2.031 "	2.068 "	1.823 "	2.574 "
3rd "	1.406 "	1.555 "	2.254 "	1.964 "
4th "	3.177 "	2.567 "	2.515 "	2.53 "
5th "	1.374 "	1.319 "	1.522 "	2.281 "
Av'ge daily gain for 5 months..	2.099 lbs.	1.98 lbs.	2.138 lbs.	2.362 lbs.

Table III shows the average daily gain per head in each lot during the period of five months. In comparing Lot I, fed a concentrated ration, with Lot II, fed a bulky ration, it may be seen that during the first three months of the period the steers on the bulky ration made the most rapid gains, while during the last two months those on the concentrated ration increased more rapidly. When the total period is considered the concentrated ration proved more effective as far as the rate of gain is concerned.

By referring to Table II it will be seen that the steers in Lot I on a concentrated ration consumed 16.66 pounds air-dry matter during the first month, and those in Lot II, on a bulky ration, 15.59 pounds,—a difference of 1.07 pounds. During the fifth month the amounts consumed were 25.50 pounds in Lot I and 22.62 pounds in Lot II, a difference of 2.88 pounds which, in a large measure, accounts for the additional gains made by Lot I as the feeding period progressed. This would seem to indicate that a bulky ration with thin cattle is just as efficient as one of more concentrated form, but as cattle fatten, concentrates become necessary if the rate of gain is to be maintained. By comparing the gains made by Lot III, when silage was extensively used, with Lot I, where it was limited, the difference is in favor of the heavy silage ration.

The results of the previous tests at this Station have shown clearly that fattening steers will make as rapid gains when fed on dry feeds in the open lot as similar cattle fed in the barn. Previous tests, however, have not included rations where the roughage consisted largely of corn silage. On account of the prevalent idea that the feeding of silage necessitates warm quarters Lot IV was fed in an open shed as compared with Lot III on a similar ration in the basement of a warm barn. Table III shows that during the winter of 1909-10, which was much colder than the average of recent years, the silage-fed cattle in the open shed made much more rapid gains than those in the barn. It should be remembered in this connection that the shed gave ample protection from wind and rain and was well bedded at all times. The gains in all lots were satisfactory for light cattle fed for five months to a high marketable finish.

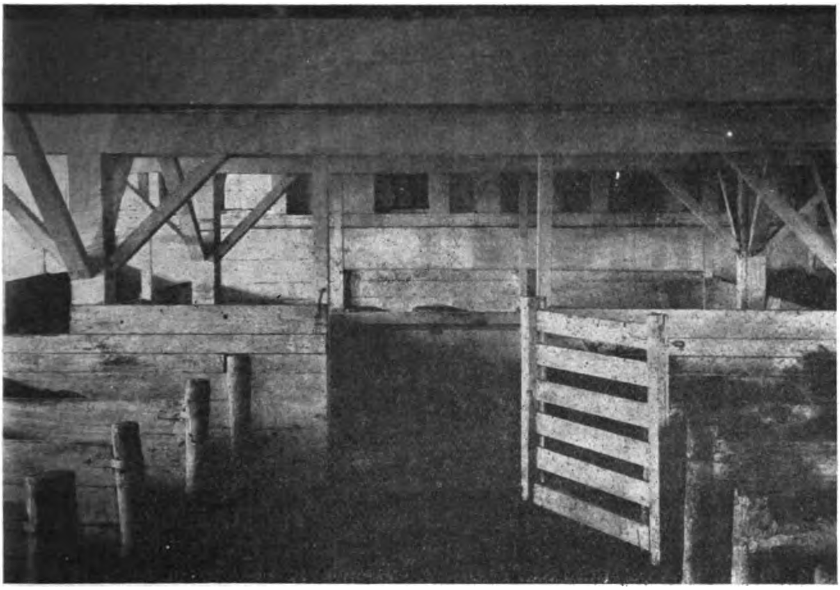

Fig. 1. Basement of College barn where steers of Lot III were fed.

A Comparison Between Bulky and Concentrated Rations.

The summary shows that Lot I, fed a heavy grain ration, made more rapid gains than Lot II, fed a medium grain ration, during the entire feeding period of 140 days. In order to make the same proportion of digestible nutrients in the rations of each lot the amount of cottonseed meal was limited to two pounds, per head, daily, in Lot I and 2.25 pounds in Lot II. It will be noted that the total amount of air-dry matter consumed was greater in Lot I. The amount of air-dry matter required to produce one hundred pounds gain is determined by the character of the feeds used, the method of feeding and the condition of the cattle at the beginning and at the close of the feeding period. In this test there was a difference in favor of the steers fed a bulky ration, due largely to the greater amount of corn silage used in this lot and to the fact that the steers were not fed to so high a degree of condition at the close of the experiment. Because of the high price of corn during the winter of 1909-10 the cost of feeding a concentrated ration was $71.98, or $6.00 per head, greater than where a bulky ration composed largely of corn silage, shredded stover and mixed hay was used. Although the gains in Lot I were more rapid the additional cost of feed made them cost $1.49 more per hundred than in Lot II. After five months feeding on a concentrated ration Lot I had cost $6.68 per hundred pounds, and Lot II $6.23, a difference of 45 cents in favor of the bulky ration. At that time the Station secured the services of Mr. J. K. Conrad to place values on all lots of cattle in the experiment on the basis of the Pittsburg market. Without being informed as to the method of feeding he valued Lot I at $7.60 and Lot II at $7.35 per hundred, a difference of 25 cents in value as compared with 45 cents in cost, showing that the demand for thicker, heavier cattle was not great enough to pay for their additional cost.

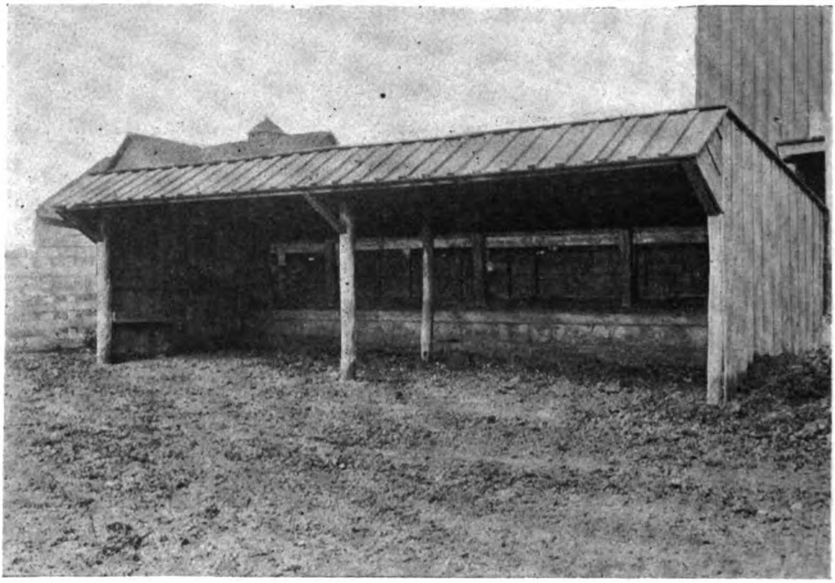

Fig. 2 Open shed where steers of Lot IV were fed.

The profit from feeding is based upon feeds at the following prices: corn, 67.7c per bushel; cottonseed meal, $34.00 per ton; shredded stover, $3.50 per ton; corn silage, $3.00 per ton; mixed hay, $12.00 per ton, and upon the selling value of the cattle on the Pittsburg market. As the experimental weights were taken after the cattle had been off water from 5 p. m. until 9 a. m., the shipping weight would show a considerable gain; there is no credit given for the amount of pork

Table IV.

FINAL SUMMARY OF EXPERIMENT.

Method of feeding	LOT I Full feed grain, ½ feed silage, roughage (in barn)	LOT II 2-3 feed grain, full feed silage, roughage (in barn)	LOT III Full feed grain, full feed silage, roughage (in barn)	LOT IV Full feed grain, full feed silage, roughage (open shed)
Length of feeding period	140 days	140 days	140 days	140 days
Initial weight, Dec. 14, 1909	9535 lbs.	9425 lbs.	9700 lbs.	9703.3 lbs.
Initial cost per cwt.	$5.00	$5.00	$5.00	$5.00
Final weight, May 13, 1910	13061.1 lbs.	12753.3 lbs.	13291.6 lbs.	13671.6 lbs.
Total gain	3526.6 "	3328.3 "	3591.6 "	3968.3 "
Average daily gain per head	2.099 "	1.98 "	2.138 "	2.362 "
Total feed consumed				
Ear corn	8480 lbs.	5572 lbs.	8540 lbs.	8540 lbs.
Shelled corn	16129 "	10918 "	16129 "	16123 "
Cottonseed meal	3172 "	3621 "	3051 "	3051 "
Shredded stover	8011 "	5027 "	3943 "	3658 "
Mixed hay	4836 "	4130 "	2815 "	3154 "
Corn silage	14380 "	28484 "	28505 "	28502 "
Total air-dry matter consumed	37745.6 lbs.	32786.86 lbs.	36859.05 lbs.	36817.68 lbs
Air-dry matter per 100 lbs. gain.	1070.29 "	985.083 "	1026.24 "	927.78 "
Total cost of feed*	$396.46	$324.48	$396.87	$ 398.34
Cost of feed per 100 lbs. gain.	$ 11.241	$ 9.75	$ 11.05	$ 10.03
Final cost cattle per cwt.	$ 6.684	$ 6.237	$ 6.634	$ 6.462
Total cost cattle and feed	$873.21	$795.73	$881.87	$ 883.49
Final value of cattle per cwt.	$ 7.60	$ 7.35	$ 7.60	$ 7.75
Final value per lot	$992.68	$937.37	$1010.16	$1059.54
Total profit per lot	$119.47	$141.64	$ 128.29	$ 176.05
Total profit per steer	$ 9.95	$ 11.80	$ 10.69	$ 14.67
Price rec'd per bu. corn	$ .971	$ 1.195	$ .992	$ 1.108

*Based on the following prices of feeds: Corn, $ .677 bu.; Cottonseed Meal, $34.00 per ton; Stover, $3.50 per ton; Silage, $3.00 ton; Mixed Hay, $12.00 per ton.

produced from the waste in feeding and no value given for manure. These three factors would more than offset the cost of shipping the cattle, hence the Pittsburg values are considered just and fair in estimating the profits. At the close of the experiment all lots were sold together, after reserving two of the best steers for instructional work, at $7.50 per hundred, weighed up full of feed and water. The actual profits are somewhat larger than indicated in the summary but the proportional amount is the same in each lot.

The results show clearly that when corn is high in price it is more profitable to feed a lighter grain ration with a greater proportion of roughage or, if the heavy grain ration is fed, that the cattle should be marketed before they become as fat as those in Lot I were at the close of the experiment. The results agree with those reported during the two preceding winters in that the chief demand in Pennsylvania is for cattle that are not made fat enough to grade as "choice" or "prime" upon the central markets, but for those that grade as "good butcher" steers or "good killers." In the opinion of all buyers who looked over the cattle Lot II was sufficiently fat for their trade while Lot I was less desirable because of the necessary waste in cutting. In every instance they preferred the steers which showed evidence of beef blood, broad, straight backs, deep bodies and short legs so necessary in making the most attractive carcasses for the consumer.

Under the conditions prevailing during the time that this experiment was in progress the steers in Lot I returned an average profit of $9.95 per head, and those in Lot II, $11.80; a difference of $1.85 in favor of the more bulky ration. After charging all other feeds at full market value Lot I returned 97.1c, Lot II $1.195 per bushel, for all corn consumed. This indicates that the most profitable method of fattening in winter is found in feeding limited grain rations combined with large quantities of wholesale roughage.

A Comparison of Different Quantities of Corn Silage for Fattening Cattle.

For many years corn silage has been considered one of the cheapest and most efficient feeds for dairy cattle. Many feeders of beef cattle have thought that, on account of its succulent nature, it is not suitable for fattening purposes. Others have considered it as an appetizer and conditioner rather than a feed. In recent years this and other stations have taken up the study of its value in many ways so that it is now recognized as one of the most valuable additions to fattening rations. A study of the summary will show that the main difference in the feeding of Lots I and III was that Lot III received a full feed of silage while Lot I received only one-half that amount. This resulted in a much larger consumption of other roughage by Lot I, though the total cost of feeding of each lot was practically the same. The additional amount of silage consumed by Lot III resulted in a slight increase in the rate of gain, a decrease in the cost of gain and an increase of $8.72 in the total profit. There was a difference of five cents per hundred in the final cost of the two lots of cattle though none in their final value per hundred on account of feeding the heavier silage ration. This test indicates that the chief value of large quantities of corn silage in rations for fattening cattle is in reducing the cost of production and increasing the rate of gain.

Fig. 3. Steers fed in barn, daily gain 2.13 pounds per head. Price returned per bushel of corn 99.2c. Profit from feeding $128.29.

The Value of Shelter for Fattening Cattle Receiving Heavy Rations of Corn Silage.

A study of the summary (Table IV) shows that Lots III and IV were fed the same amounts of corn, cottonseed meal and corn silage with other roughage approximately the same. The only difference in the method of feeding was that Lot III was kept in a large box stall in the basement of the College barn, where all conditions were apparently most favorable for rapid and economical gains, while Lot IV was kept in an open lot in which was an open shed 12x30 feet, where the feeding was done. The shed was kept well bedded so that the cattle might have a dry place to lie down at all times. These two methods of feeding have been used at the Station during the six preceding winters, but in every instance the two lots of cattle were fed rations which contained no silage. The results were favorable to open-shed feeding during those tests. There has been a general impression among feeders that the use of corn silage necessitated greater protection of the cattle against cold; that, on account of its succulent and laxative nature, the cattle would suffer if not kept in warm quarters. For this reason the experiments here reported included a comparison in which a heavy silage ration was fed in open shed to Lot IV as compared with a similar ration to Lot III in the basement of the College barn.

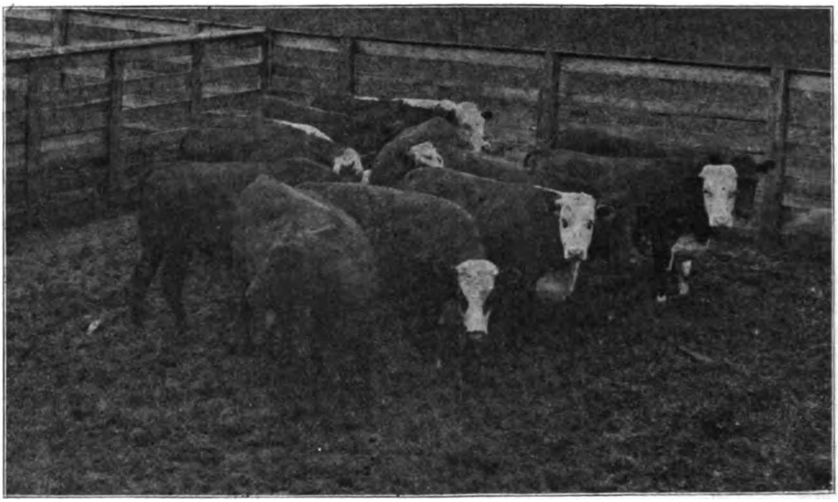

Fig. 4. Steers fed in open shed, daily gain 2.36 pounds per head. Price returned per bushel of corn fed $1.108. Profit from feeding $176.05.

The results show that the steers fed in the open shed made more rapid gains at a saving of $1.02 in cost per hundred pounds. At the close of the experiment they had cost 17.2c. per hundred less and were valued at 15c. per hundred more than those in the barn. The profit per head from open-shed feeding was $14.67, and from feeding in barn $10.69, a difference of $3.98 per head or an increase of 11.6c per bushel in the value of corn fed to the cattle out of doors over that fed in the barn. This demonstrates clearly that full feeding of cattle is more profitable from every standpoint if they are given ample protection from wind and rain, without protection from cold even where they are allowed a maximum amount of corn silage.

The Fertilizer Value of Feeds.

While the discussion presented in connection with the summary of results has not taken into consideration the manurial value of feeds, this is one of the most important phases of the study of beef production. The chief profit derived from steer feeding comes from the increase of crop yields due to an intelligent use of manure.

Table V.

SHOWING FERTILIZER VALUE OF FEEDS.

Feed Consumed		Plant Food Contained in Feeds*			Total Value†
		Nitrogen	Phosphoric Acid	Potash	
LOT I.	Ear Corn	119.57 lbs.	48.34 lbs.	39.85 lbs.	
	Shelled Corn	293.55 “	112.90 “	64.51 “	
	Cottonseed Meal	215.38 “	91.35 “	27.59 “	
	Shredded Stover	83.31 “	23.23 “	112.15 “	
	Corn Silage	40.26 “	15.82 “	53.21 “	
	Mixed Hay	80.28 “	21.76 “	74.96 “	
	Total	832.35 lbs.	313.40 lbs.	372.27 lbs.	
	Value	$166.47	$15.67	$18.61	$200.75
LOT II.	Ear Corn	78.56 lbs.	31.76 lbs.	26.19 lbs.	
	Shelled Corn	198.71 “	76.43 “	43.67 “	
	Cottonseed Meal	245.86 “	104.28 “	31.50 “	
	Shredded Stover	52.28 “	14.58 “	70.38 “	
	Corn Silage	79.75 “	31.33 “	105.39 “	
	Mixed Hay	68.56 “	18.58 “	64.01 “	
	Total	723.72 lbs.	276.96 lbs.	341.14 lbs.	
	Value	$144.74	$13.85	$17.05	$175.64
LOT III	Ear Corn	120.41 lbs.	48.68 lbs.	40.14 lbs.	
	Shelled Corn	293.55 “	112.90 “	64.51 “	
	Cottonseed Meal	207.16 “	87.87 “	26.54 “	
	Shredded Stover	41.01 “	11.43 “	55.19 “	
	Corn Silage	79.81 “	31.35 “	105.61 “	
	Mixed Hay	46.73 “	12.67 “	43.63 “	
	Total	788.67 lbs.	304.90 lbs.	335.62 lbs.	
	Value	$157.73	$15.24	$16.78	$189.76
LOT IV.	Ear Corn	120.41 lbs.	48.68 lbs.	40.14 lbs.	
	Shelled Corn	293.44 “	112.86 “	64.49 “	
	Cottonseed Meal	207.16 “	87.87 “	26.54 “	
	Shredded Stover	38.04 “	10.61 “	51.21 “	
	Corn Silage	79.90 “	31.35 “	105.46 “	
	Mixed Hay	52.36 “	14.19 “	48.89 “	
	Total	791.31 lbs.	305.56 lbs.	336.73 lbs	
	Value	$158.26	$15.28	$16.84	$190.37

***Based upon averages given by “Feeds & Feeding,” Henry.**

†Based upon the following prices: Nitrogen, 20c per lb.; Phos. acid, 5c per lb.; Potash, 5c per lb.

Table V shows that the nitrogen, phosphoric acid and potash contained in the feeds used in this series of experiments, if replaced in the form of commercial fertilizer at twenty cents per pound for nitrogen, and five cents per pound for phosphoric acid and for potash, would cost $756.52, or an average of $15.76 for each steer fed. While the steers would remove a small portion of these materials from the farm when sold on the market and there would be a further loss from leaching of manure, the average feeder can easily return to the land sixty per cent. of all the plant food consumed by his livestock. This would amount to approximately two (2) dollars per month for each steer, which is a matter worthy of consideration in steer feeding. It may also be noted that the most concentrated ration used in these tests, that fed to Lot I, had the greatest amount of plant food in it, while the more bulky ration, that fed to Lot II, had the least. This shows that in purchasing concentrated feed for livestock there is a large amount of fertilizer material gained in addition to the feeding value, which helps to build up the land.

General Conclusions.

The results secured from the experimental work of the winter of 1909-1910 indicate that:

1. The most economical ration for fattening steers in Pennsylvania is one composed largely of roughage with a limited amount of concentrates.

2. The local demand for beef is such that the cattle should not be carried to too high a degree of finish.

3. Increasing the proportion of corn silage in ration for fattening steers increases the profits and gains from the feeding.

4. Protection from cold is as unnecessary for fattening cattle on succulent feeds as when dry feeds are used.

5. Steer feeding was a profitable venture in Pennsylvania under conditions prevailing at the Experiment Station from December 15, 1909, to May 3, 1910, the average price received for corn fed to experimental cattle being $1.05 per bushel.

6. The margin necessary between buying and selling prices to prevent loss from fattening cattle on a bulky ration was $1.23 per cwt., and on a concentrated ration, $1.68 per cwt. The difference in margin necessary for feeding in the shelter experiment was 17.2c. per cwt. in favor of outdoor feeding.

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 103

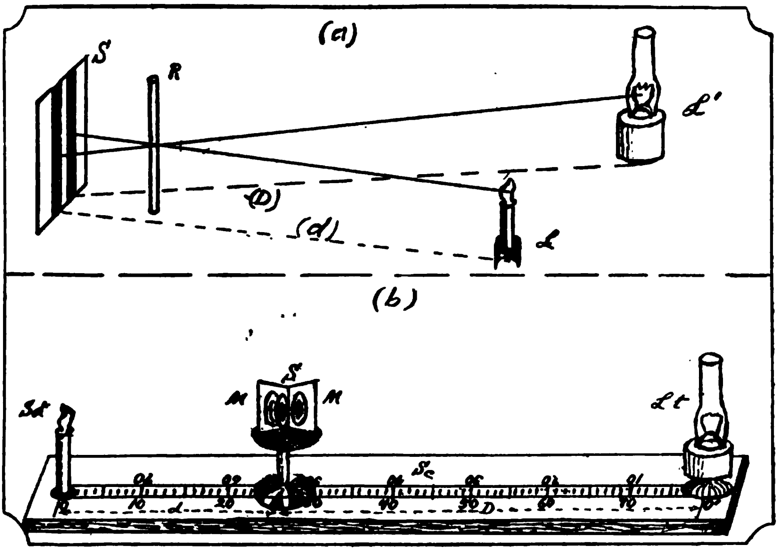

Fig. 1.

THE LIGHTING OF FARM HOUSES

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
SEPTEMBER, 1910

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* Absent on Leave.
† Assigned by the Bureau of Soils, U. S. Dept. of Agr.

The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 103

THE LIGHTING OF FARM HOUSES

Comparison of Kerosene, Gasolene, Acetylene and Alcohol

By I. THORNTON OSMOND

Introductory.

There are about two hundred and fifty thousand farm houses in Pennsylvania, and they must all be lighted. The cost of lighting them is a considerable item in the annual expenses of the quarter million households. Can equally good illumination be had at less cost? Or at the same cost, can better illumination be obtained? In the city, the householder finds his house already provided with means for gas lighting or electric lighting, or it may be for both. Neither of these can be had in the farm house, except in so few instances that they need not be considered. Practically, the kerosene lamp is the present means of lighting the farm houses of our State. But there are three other means of household lighting for which strong claims are made, the gasolene lamp, the portable acetylene lamp, and the (denatured) alcohol lamp.

The question of economy in lighting is of considerable importance, and well worth some labor to determine. But of far greater importance is the sanitary question, the bearing on health and efficiency or illness and inefficiency. And there is a third consideration of great importance, the pleasure, the attractiveness, of a fine illumination that adds cheer and charm to the evening hours at home.

Beyond the question of economy, every farm house should be as sanitarily and as attractively lighted as any city house.

Candle Power.

Our great grandfathers, and their fathers, used candles to light their houses; so when our grandfathers got to using other kinds of lights it was natural that they should compare them with the candle, and rate them in "candle power," just as the steam engine which took the place of horses in doing work was rated in "horse power." Certain specifications as to what should constitute the standard candle were long ago adopted in Great Britain, Germany and the United States.

The British and American *standard candle* is a sperm candle, seven-eighths inches in diameter, weighing six to the pound, burning 120 grains (7.776 grams) of sperm per hour. In Germany, the standard candle of paraffin has been supplanted by the Hefner lamp, burning amyl acetate. Though the light from this lamp is fairly uniform in intensity, while that from a candle is quite variable, it has not been much used in this country. Various other standards than those mentioned have been used more or less.

The International Unit of Light, maintained by the National Physical Laboratory of England, by means of the Pentane lamp, and which may not be exactly equal to the standard sperm candle, became the legal unit of light in the United States on July 1st, 1909.

In the following work the legal sperm candle is the standard. By direct comparison with such a standard, at each time of doing work, a kerosene lamp was *standardized* and then this lamp was used as the *working standard* with which the other lights were measured. This is like measuring a pole with a foot rule and then using the pole to measure large distances; the foot rule is the standard of measurement, but the pole is the working standard.

Principle of Photometry.

Through a spherical surface, of any radius, about a light source, all the light passes; and this same amount of light passes through any spherical surface about the source as centre. The surface of twice as great radius as another will have four times as many units of area as that other; that with three times as great a radius, nine times as many units of area, and so on. Hence the amount of light per unit area, or intensity of illumination, anywhere in the region about a light source, is inversely as the square of the distance from the light source.

And, also, the intensity at any distance is directly proportional to the total amount of light given per unit time by the source. Thus, if L and L1 are the quantities of light from two sources which give the same intensity of illumination, I, of a surface when they are at distances d and D from the surface,

$$I = \frac{L}{d^2}, \text{ and } I = \frac{L^1}{D^2}$$

$$\text{Or. } L : L^1 : : d^2 : D^2$$

If the candle power of L is known, and if d and D have been determined by trial, the candle power of L1 may be calculated.

Photometer.

The photometer used in this work is of the Bunsen type (Fig. 1). The mirrors were cut from a piece of very fine plate glass mirror. Several discs, "grease spots," were made by carefully spreading paraffin dissolved in refined turpentine over both sides of a "spot" on paper of different kinds, until one was found, or made, in which the disappearance of the "spot" was unusually perfect on both sides of the paper, and moreover occurred on both sides of the paper (for similar lights) at practically the same position of the spot-screen on the bar. The spot-screen and mirrors were so mounted in the box as to be easily revolved about a vertical axis. The box was movable along a base on which two positions were marked two metres (82.75 inches) apart, one for the standard light and the other for the light being measured, and a scale numbered both ways enabled the distance of the "spot" from each light to be directly read.

Method of Using.

The box was moved toward one of the lights until there was a decided appearance of the spot (dark), then moved off until the spot disappeared, and the position of the spot-screen on the scale noted; then the box was moved toward the other light until the spot appeared (dark), then moved off until it disappeared, and the position noted. The mean of these two positions was taken on the scale and its distance from each light read and recorded. Then the spot-screen and mirrors were revolved 180 degrees, and the above process of making a reading repeated.

Materials Used.

The kerosene used was obtained from grocery stores supplied by the Atlantic Refining Co., weighing 6.39 pounds per gallon, at 70 degrees F.

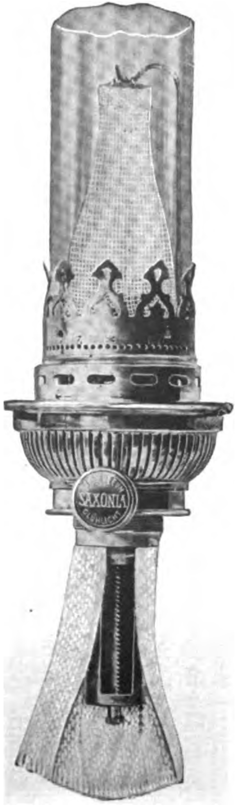


Fig. 2.

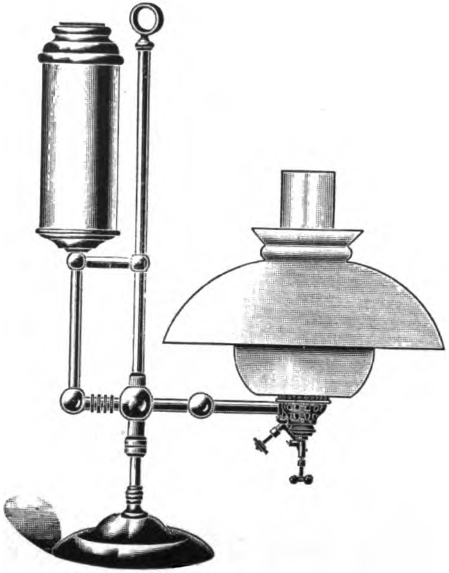


Fig. 3.

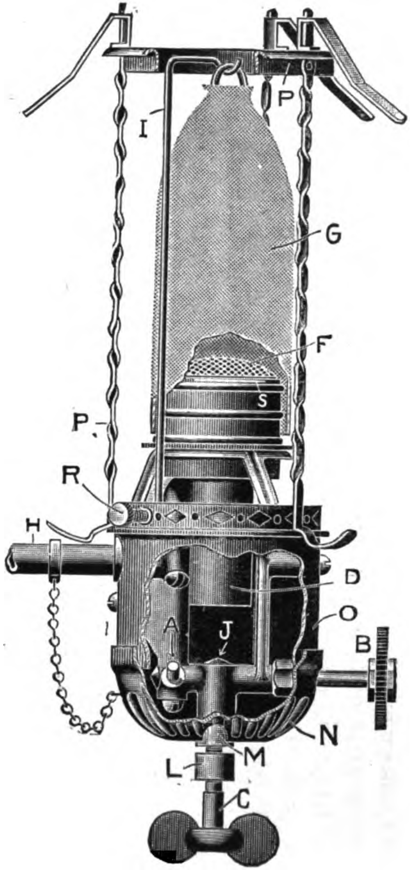


Fig. 4.

The gasolene used, at 68 degrees Fahrenheit was 68 Beaumé, on correcting for temperature, 70 Beaumé, weighing 5.73 pounds per gallon, at 70 degrees F.

The acetylene gas was obtained from calcium carbide of the grade known as electrolite.

The alcohol was the denatured alcohol used for heat and in the arts, weighing 6.22 pounds per gallon, at 70 degrees F.

Lamps Used.

1. A common kerosene lamp with flat wick, 1½ inches wide, circular chimney, 8½ inches high, various diameters, "pearl top."

2. A kerosene lamp, Rochester, with Argand burner, 1½ inches diameter wick, chimney nine inches high.

3. A kerosene lamp, Saxonia, with Argand burner, ⅞-inch diameter wick, and mantle, cylindrical chimney 1¾ inches diameter and 12 inches high. Fig. 2.

4. A gasolene lamp, Best, underneath generator pattern, with a fuel head (average) about 16 inches above the aperture of burner, mantle 4 inches high with three and three-fourth inches exposed to flame, cylindrical chimney 1⅞ inches diameter and 8 inches high. Fig. 3 and Fig. 4.

5. An acetylene lamp, Beck-Iden, carbide to water feed, ½ foot Schwarz burner. Fig 5 and Fig. 6.

6. An alcohol lamp, Pyro, Argand burner, 3-inch mantle with 2¾ inches exposed to flame and supported on a metallic centrepost, cylindrical chimney 1⅞ inches diameter and 9 inches high. Fig. 7.

7. A kerosene lamp, Canchester, with Argand burner, ⅞-inch diameter wick surmounted by a carbon cylinder, and mantle, cylindrical chimney 13½ inches high.

Also a kerosene lamp with a Bing burner, Fig 8, (see paragraph on Bing burner); a kerosene lamp with flat wick ½ inch wide (see width of wick and consumption per candle power); and a kerosene lamp, 1½-inch flat wick, used as a *working standard*, explained below.

Working Standard.

As stated above, the standard, or unit, of illuminating power used in this work is the legal *standard candle*, the light from a sperm candle burning 120 grains per hour. But it is impracticable to use a candle, or two candles, in the photometer with a light so strong as some here used. So, a kerosene lamp, after burning a little to become steady,

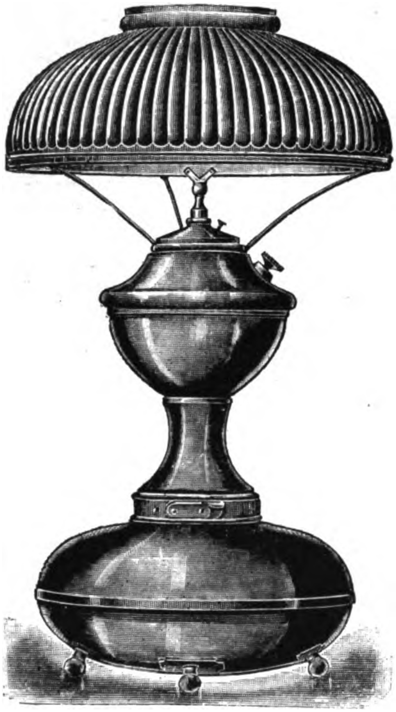


Fig. 5.

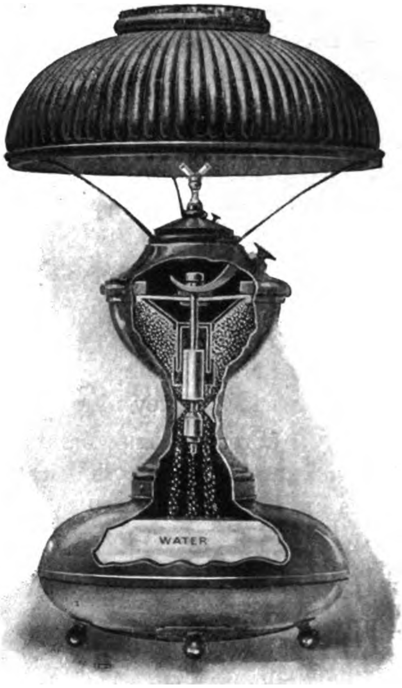


Fig. 6.

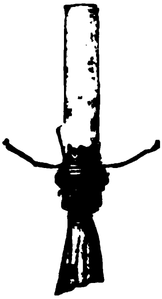
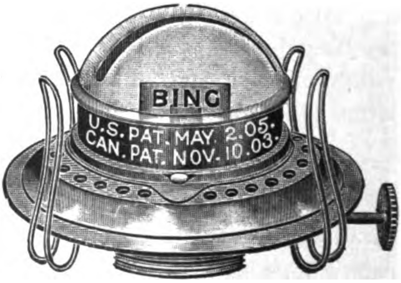


Fig. 7.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CAN. PAT. NOV. 10.03.

Fig. 8.

was *standardized,* for each set of tests, by measuring its candle power by means of two sperm candles, whose rate of burning was determined and their value corrected accordingly. Then this *standardized* lamp (about 10 or 12 candle power) was used as a *standard* of light, a *working* standard, and each of the six lamps under comparison was measured by it. All the six lamps being thus compared with, measured by, the same light, their ratios to each other are unaffected by any error in the absolute number of candle powers of the working standard.

This working standard was again *standardized* at the close of each set of tests of the six lamps, and the mean of the two values found was used in calculating the set.

Record of Experimental Tests and Results.

The complete record of all the measurements for one set of tests of the lamps is given in Table 1, Annual Report of The Pennsylvania State College, for the year 1908-1909; and Table 2 contains the results of seven such sets of tests of the lamps with the different illuminants. Only the latter, Table 2, is given in this Bulletin.

Notes.

1. Much care was taken to have the candles, while *standardizing* the working standard, in good burning condition, for the amount of light given by candles is not dependent solely on the rate of burning sperm nor exactly proportional to that rate simply. This good burning condition would tend to lessen slightly the numerical value of the candle power of the working standard. This, again, would make the candle power of the lamps numerically slightly less than if the candles had been used in poor condition, and likewise the numerical value of the candle power hours per gallon (or pound). While this would slightly increase the cost per candle power hour, the effect is too small to change by one unit any of the figures of cost, unless possibly the .043 of a cent found for acetylene might have become .042, and the .086 of a cent for alcohol might have become .085 or .084, if only moderate care or a little negligence had been given the candles when standardizing with them.

2. The candle power as found from the carefully burned candles would probably be increased about 10 or 12 per cent. if the unit of the Reichsanstal standards, the Hefner, had been used.

3. While the exact measurement of any light, as light in candle power, is impossible, since there is no concrete standard, or physical

Table II. Results of Seven Sets of Tests of Seven Lamps, Burning Kerosene, Gasolene, Acetylene and Alcohol.

LAMP AND MATERIAL	Duration of Test	Amount of Material Used	Candle Power Developed	C. P. Hours per Gallon	Cost of 1 C. P. Hour	Mean Cost of 1 C. P. Hour
	H. M.	Gal.			Cent.*	Cent.*
No. 1. Flat wick, 1½ inches wide, burning kerosene.	2 35	0.044	12.91	757.96	.0145	.017
	4 00	0.078	12.17	621.76	.0177	
	3 00	0.059	11.66	591 87	.0186	
	4 20	0.064	11.66	789.19	.0139	
	3 00	0.048	12 14	758.75	.0158	
	4 00	0.070	11.92	681.14	.0161	
	4 00	0.068	11.90	699 99	.0157	
No. 2. Argand, 1½ inches diameter, burning kerosene.	2 40	0.122	16.02	350 16	.0314	.023
	4 00	0.137	17.74	518.06	.0212	
	3 00	0.103	18.48	538.77	.0204	
	4 20	0.171	19.04	482 64	.0228	
	3 00	0.119	18.03	454 61	.0246	
	4 00	0.149	18 11	486.18	.0226	
	4 00	0.146	18.54	538.42	.0204	
No. 3. Argand, ⅞ inch diameter, and mantle, burning kerosene.	2 00	0 043	30.26	1,407.42	.0078	.008
	4 00	0 085	30.21	1,515.80	.0072	
	3 00	0.062	28.07	1,382.76	.0078	
	4 00	0.083	27.92	1,342.22	.0082	
	3 00	0.060	27.46	1,373.00	.0080	
	4 00	0.087	30.18	1,387 58	.0080	
	4 00	0.081	28.94	1,429.16	.0077	
No. 4. Pressure (average) 16 in. of fluid, burning gasolene.	1 4	0.016	36.00	2,399.98	.0064	.008
	4 20	0.094	36 64	1,597.91	.0094	
	3 00	0.063	37.24	1,773.37	.0085	
	4 00	0 093	40.86	1,757.43	.0085	
	3 00	0.060	46.00	1,974.27	.0076	
	4 00	0 091	39.12	1,719.38	.0087	
	4 00	0.089	43.43	1,974 08	.0076	
No. 5. ½ foot gas burner, burning acetylene.	0 55	2.5	24.02	†140.80	.0449	.043
	4 15	11.5	21.62	127.81	.0460	
	3 00	8.1	22.87	185 50	.0434	
	4 00	10.0	23.23	148.67	.0395	
	3 00	7.4	22.02	143.82	.0412	
	4 00	10.6	22.45	135.56	.0434	
	4 00	10.4	22.63	139.27	.0442	
No. 6. Burning, with mantle, denatured alcohol.	2 30	0.064	22.68	898.85	.0834	.086
	4 15	0.107	21.06	885.76	.0898	
	3 00	0.075	20.87	834.80	.0898	
	4 00	0.105	21.76	828.95	.0905	
	3 00	0.079	24 02	921.89	.0815	
	4 00	0.104	20.97	806.51	.0929	
	4 00	0.101	22.90	907.78	.0825	
No. 7. Burning kerosene, ⅞ inch Argand with carbon-cylinder wick-top and mantle.	2 00	0.019	32.400	3,402.32	.0032	.0034
	2 00	0.019	30.720	3,233.59	.0034	
	2 00	0 020	32.400	3,240.00	.0034	
	2 00	0.019	30 600	3,220.96	.0034	
	2 00	0.020	32.400	3,240.01	.0034	
	2 00	0.020	31.344	3,184.00	.0035	
	2 00	0.019	31.200	3,284.11	.0033	

† Per pound (instead of gallon) of calcium carbide, electrolite. * See Note 4.

embodiment of a unit of light (as light), this does not affect in any way the *ratios* of the numbers found for candle power hours per gallon (or pound) nor the *ratios* of the numbers found for cost per candle power hours, since all measurements were made against the same thing, the *working standard,* and it is these *ratios* that we are concerned with in this comparison of different substances as sources of illumination.

4. In calculating the cost per candle power hour the following prices were used: Kerosene, 11 cents per gallon; gasolene, 15 cents per gallon; alcohol (denatured), 75c per gallon; calcium carbide (Electrolite) 5 9-10 cents per pound.

5. The intensity of the light from a lamp with a flat flame is generally unequal in different directions, slightly less light being given off by the edges than by the flat side. Lamps No. 1 and No. 5 have flat flames, and the intensity of the light from the broad sides was measured. The intensity in different directions around a flat acetylene flame usually varies but little; the variations around a flat kerosene flame are greater.

Bing Burner.

This is widely advertised, with the attractive legend "One-third more light." The only essential difference from the ordinary flat wick kerosene burner is the substitution of a glass dome for the usual brass dome over the wick.

As all the luminous part of a flame of a lamp when burning anywhere nearly full rate is above, outside of, the dome, whether this dome is transparent or opaque can evidently make no difference in the amount of light given out. The following test, however, was made.

The Bing burner was put on one lamp and a common burner for same width of wick on another lamp; both supplied with new wicks exactly alike, and chimneys just alike. Both lamps were burned awhile and the wick rubbed off to give good regular shaped flames. The oil in both lamps was from the same can. Both wicks were turned up until the least further turning up caused smoking. Both lamps were burned 58 minutes, and burned the same quantity of oil.

While the lamps were burning ten measurements were made on the photometer, the mean of the ten showing the lamps to be equal.

Instead of "One-third more light," the quantity of light given by the Bing burner is practically the same as that given by the common metallic dome burner with the same width of wick.

When, however, a lamp is turned low, so that all, or nearly all, the flame is within the dome of the burner, the common burner gives out very little light, while the Bing burner with its transparent dome gives out considerable light, so that in many instances the Bing burner may be worth much more than its trifling additional cost.

Width of Wick and Consumption Per Candle Power.

A was a lamp with a flat wick ½ inch wide.

B was a lamp with a flat wick 1½ inches wide.

Both were burned 4 hours, A consuming 3.5 ounces of kerosene, and B consuming 7.5 ounces.

The larger lamp consumed 2.14 times as much oil per hour as the smaller, and gave 2.23 times as much light.

A single experiment like this is not proof of a law, but it illustrates the law that, all other things being alike, the larger lamp is the more efficient apparatus for making light.

Quality of Light.

So far only the quantity of light, the intensity, or candle power of illumination, has been considered. But lights differ greatly in another very important respect, as to *quality*. This is due to the exceedingly complex composition of light. A narrow beam of white sunlight passing through a prism is separated into "all the colors of the rainbow," a normal eye recognizing six or eight, usually said to be seven. A little training of the eye and careful looking will show, further, that each of these seven colors is by no means simple. And a physical instrument called a spectrometer shows that the spectrum, the band of rainbow colors, consists of many thousands of colors. Now, the *quality* of any light depends on the *relative* amounts of each of these thousands of thousands of colors that it contains.

For the comparison of lights as to quality it is impossible to take account of each of the thousands of components in them, it is convenient, and sufficient for practical purposes, to take them in great groups, the seven which the normal eye recognizes in the spectrum or rainbow. Selecting a component in each of these groups, the intensity of a little portion of the light close to and very nearly like this component is measured in both lights and compared (by means of a spectrophotometer). See such comparisons below. It is assumed that the ratio of intensity found for these little portions holds nearly true through the group in the two lights. If greater accuracy of comparison is required, a greater number of components must be used.

Sanitary Relations of Quality—Daylight the Normal Light.

According to good medical authorities the strain and injury to the eyes caused by much use in reading, sewing, etc., by poor artificial lights, does not stop with the injury and pain of the eyes only, but are liable to be the inception of some of the host of nervous diseases, neuralgia, nervous headache, nervous dyspepsia, brainfag, mental depression, or other ills due to waste of nervous energy. A poor light may be cheap, but its use is awfully poor economy when the toll it takes of health and happiness is considered.

Dr. Edward L. Nichols, of Cornell University, says: "The human race, as I pointed out in a paper read before the National Academy of Sciences, having been developed in sunlight, has its organs of vision adapted, by long ages of exposure, to that particular stimulus. It is not to be regarded as a coincidence, then, but as the result of evolution rather, that the maximum luminosity for the normal eye is in the same region of the spectrum as the maximum of the energy of sunlight. Since primitive man, moreover, was not nocturnal in his habits, the range of sensitiveness of his eye is for daytime use, and he does not see as well by night as cats or owls. It is the extension of our activities to the hours of darkness, under the conditions of our new civilization, that has made artificial lighting necessary and brought into existence the important profession of the illuminating engineer. The acceptance of daylight as an ideal or standard by which to gauge our existing methods of artificial illumination, to determine its shortcomings and to indicate what to strive for and what to avoid, has a sound philosophical basis.

"We may take as a general principle that *the normal stimulus of the eye is diffused daylight, and that artificial stimuli which depart widely from it either as to intensity or quality are sure to be unsatisfactory and are likely to be injurious.*"

But what is "daylight," the acceptance of which as a standard to strive for in artificial lighting "has a sound philosophical basis?"

Manifestly sunlight varies much in composition, with time of day, atmospheric conditions, altitudes, etc. Dr. E. L. Nichols has measured the intensities of components in various parts of the spectrum on the ocean and on the Swiss Alps, and elsewhere; Langley, the relative energy (nearly proportional to luminous intensity) in Pittsburg and on a summit of the California Sierras; Basquin, in Chicago; Koettgen, in Berlin, and others. So, the composition of sunlight, and the range of its variation in quality, are quite well known.

"Daylight" is the illumination of an unshaded surface. It is derived exclusively from the sun, but it is modified sunlight, for part of it has been reflected, with changes of quality, from minute particles in the atmosphere, from cloud masses, and from the surface of the earth.

Since the direct sunlight is much the greater part, although there are changes in the smaller reflected part, daylight differs from sunlight but little in quality.

From a large number of observations made by Dr. Nichols, during the hours of full daylight, in various places, near sea-level or at moderate altitudes, in the varieties of weather and of season occurring during a period of about six months, the averages furnish a standard of "daylight" with which to compare artificial sources of illumination.

The average intensities of components in seven places in the daylight spectrum (in terms of the acetylene flame), derived from the above work, are as follows:

Wave-lengths*	.725	.620	.590	.530	.460	.420	.390
Colors	Red	Orange	Yellow	Green	Blue	Blue Violet	Violet
Intensities	.490	.866	1.00	1.31	1.87	2.34	2.67

* In microns, about 1-25000 inch.

The production of an acetylene light of an exact intensity and of entirely invariable quality cannot be accomplished. But freshly prepared acetylene, from good carbide, by proper process, burned from a standard burner, is a pretty good approach to such a light; moreover, it is readily attainable at almost any time and place. Thus it serves fairly well as a standard for the comparison of other lights, by comparing each with it. A light is nearer like daylight as the intensity of the red in it approaches about half that of the red in the acetylene light, the orange about four-fifths, the green about four-thirds, the blue about nine-tenths, the blue-violet about seven-thirds, and the violet about eight-thirds, when the light has such intensity as to make the yellow in it equal to the yellow in the acetylene light.

Comparison of Lights Used With Daylight.

The sources of light compared in the present work are of three classes, as follows:

Class I.—Kerosene Flame: Lamps 1 and 2.

Class II.—Acetylene Flame: Lamp 5.

Class III.—Incandescent Oxids (Mantle): Lamps 3, 4, 6 and 7.

For comparing the *quality* of each of these with "daylight," I have arranged Table III, from data given in a paper read by Dr. E. L. Nichols before the Illuminating Engineering Society.

Table III.

Wave-lengths in Microns*	LOCATED IN COLOR	Kerosene Flame	Acetylene Flame	Incandescent Oxids‡
.700	Red,	2.650	1.847	1.400
.650	Orange,	1.840	1.381	1.160
.590	Yellow,	1.000	1.000	1.000
.550	Yellow-green,	0.708	0.785	0.838
.500	Blue-green,	†.479	.598	.636
.460	Blue,	†.303	.452	.431
.420	Blue-violet,	†.202	.368	.297
.390	Violet,	....	.370	... .

* About 1-25000 inch.
† These measures are at slightly different wave-lengths from those given opposite them.
‡ A new Welsbach mantle, on a gas flame.

If we take a kerosene flame and, without any change of its *quality*, increase its intensity until the yellow in it is equal to the yellow in "daylight," the red in it will be 2.65 as great intensity as the red in "daylight," and the orange 1.84 as great intensity as the orange in "daylight," while the green will be not much over half and the blue less than half, as intense as they are in "daylight," and the violet is practically absent. This is a wide departure in quality from the normal light required for the healthful use of the eye.

If we take an acetylene flame, without any change of its *quality*, make its intensity such that the yellow in it equals the yellow in "daylight," the red in it will be but 1.85, and the orange but 1.38, as intense as in "daylight," while the green will be about three-fourths, the blue about one-half, and the violet more than one-third, their intensities in "daylight." There is much less excess of red and orange, and much less deficiency of green, blue and violet lights, than in the kerosene flame. It is much more like daylight, the light to which evolution through centuries has adapted the human eye, and by which it works easiest and longest with least injury.

The light from incandescent oxids (mantles), so far as indicated by the study of the Welsbach mantle given in Table III, is quite as good in respect to the red and orange as the acetylene flame, or a little better, but it is considerably more deficient in blue and violet than is acetylene, an important defect in quality, making it a less true "white" daylight than the light from the acetylene flame.

How nearly the quality of the light from the mantle made incandescent by the kerosene flame (Lamps 3,7), or of that from the mantle made incandescent by the gasolene flame (Lamp 4), or of that from the mantle made incandescent by the alcohol flame (Lamp 6), is represented by the light from the Welsbach mantle on gas flame given in Table III, can be determined only by experiments beyond the range of the present work. To the eye there are, apparently, some differences, but since so large a part of the light comes from the mantle in each case, it seems probable that with burners and chimneys so constructed as to secure nearly equal temperatures, and with the same material in the mantles, the differences in the quality of light from using any of the four kinds of flame should not be very great. This whole subject of the effect of the chemical and physical properties of mantles and of their sources of heating and temperatures on the radiations from them needs further investigation.

Other Sanitary Relations of Lighting.

All these lights affect health in two other ways, by the production of heat, and by taking oxygen from the air and giving out carbon dioxid. The former, heating, is generally objectionable and very frequently injurious in the use of some of the lights, the latter, vitiation of the air by carbon dioxid, is always injurious.

In these respects the six lamps, four materials, are compared in Table IV.

Table IV—Per 100 Candle Power Hours.

Lamps	MATERIAL	Heat Produced. Large Calories	Oxygen Consumed Cubic Feet	CO_2 Formed Cubic Feet
No. 1	Kerosene,	4,937	35.7	23.9
No. 2	Kerosene,	7,325	51.9	33.3
No. 3	Kerosene,	2,508	17.8	11.4
No. 4	Gasolene,	1,634	11.7	7.9
No. 5	Acetylene,	1,342	10.1	8.0
No. 6	Alcohol,	2,273	16.3	10.8
No. 7	Kerosene,	1,080	7.6	4.9

This table is calculated from the means of the candle power hours per gallon (or pound) for each material as found in Table II, by using the heats of combustion of hydrogen and carbon, assuming that the kerosene may be represented by $C_{10}H_{22}$ (average for mixture), the gasolene, by C_7H_{14} (average for mixture); acetylene, by C_2H_2 (definite compound), and alcohol, by C_2H_6O (grain alcohol). 96 per cent. grain alcohol denatured as specified by law, will produce about 2 per cent. less heat, consume about 3 per cent. less oxygen, and form about 3 per cent. less carbon dioxid; and all the materials used for illuminants, as purchased in market, have more or less impurities which will make all the quantities somewhat less than found by calculation.

Most readers, perhaps, will get a better idea of the amounts of heat produced from the various lamps and materials if they are expressed, not in calories as in the table, but in quantities of water and rise of temperature, as follows:

For 100 candle power hours, the heat from

Lamp 1, will raise 111 lbs, of water from 32 F. to 212F.
Lamp 2, will raise 166 lbs. of water from 32F. to 212F.
Lamp 3, will raise 57 lbs. of water from 32F. to 212F.
Lamp 4, will raise 36 lbs, of water from 32F. to 212F.
Lamp 5, will raise 30 lbs. of water from 32F. to 212F.
Lamp 6, will raise 50 lbs. of water from 32F. to 212F.
Lamp 7, will raise 24 lbs. of water from 32F. to 212F.

In the properties included in Table IV, acetylene is many times better than the ordinary kerosene flame, is decidedly superior to gasolene and alcohol, and is equalled only by the Canchester kerosene burner.

Some Minor Points.

In *portability* the kerosene, gasolene, and alcohol lamps do not differ materially. The acetylene lamp, owing to the water reservoir in the base, is somewhat less readily picked up and carried about, though easily portable from room to room, or up and down stairs.

The *renewal* of broken chimneys adds more or less to the cost of lighting by all the others but acetylene.

The *labor* and *time* required to take care of the lamps is practically the same for gasolene and alcohol, but alcohol is much safer and pleasanter to work with than gasolene. Kerosene and acetylene lamps require about equal time and labor, a little more than the two former.

In *danger* from having the different materials about and working with them, gasolene is most dangerous, kerosene perhaps next, alcohol next, and calcium carbide (for acetylene) the least dangerous of all The danger from the use of these different materials in lamps is, probably, in the same order, but opinions may differ on this.

Home Measurements of Lights.

Probably in a great many Pennsylvania farm homes there is some boy or girl who would find pleasure in measuring the lights used. A very simple photometer, capable of pretty good work, which can be constructed without any cost, by any such boy or girl, in any home, is illustrated in Fig. 1. (a). Place a stick, R, about the size of a pencil or penholder, about three inches in front of a vertical sheet of white (unglazed) paper, S. Arrange the two lights to cast shadows close together on the paper, and adjust the distances of the lights from the paper so that the two shadows are equally dark. Then, as before explained, if L and L_1 are the amounts of light, or candle powers, of the two lights, $\frac{L}{(d)^2} = \frac{L^1}{(D)^2}$; L_1 is $\frac{(D)^2}{(d)^2}$ times as strong a light as L.

Summary.

1. The quantity of light, number of candle power hours, given by one gallon of each of the substances used, is for:

Kerosene, using flat wick 1½ inches wide	700.13
Kerosene, using Argand (central draft) burner 1½ inches diameter,	481.27
Kerosene, using Argand burner ⅞ inches diameter, and mantle, carbon-cylinder wick-top,	3250.71
Gasolene, using pressure (average) of 16 inches of fluid,	1885.21
Alcohol (denatured),	872.00
Acetylene, using ½ foot gas burner, per pound of carbide,	138.79

2. Assuming the following prices, kerosene 11 cents per gallon, gasoline 15 cents per gallon, alcohol (denatured) 75 cents per gallon, and calcium carbide (Electrolite) 5 9-10 cents per pound, the cost of a candle power hour from each is:

Kerosene, flat wick, 1½ inches wide	.017 of one cent
Kerosene, Argand burner, 1½ inches diameter,	.023 of one cent
Kerosene, Argand, ⅞ inch diameter, and mantle	.008 of one cent
Kerosene, Canchester burner, and mantle,	.0034 of one cent
Gasolene, pressure of 16 inches of head,	.008 of one cent
Acetylene, ½ foot burner,	.043 of one cent
Alcohol (denatured),	.086 of one cent

Larger sized carbide for large (nonportable) generators costs only 3.8 cents per pound, giving one candle power hour from acetylene for .028 of one cent.

3. The Saxonia burner, Argand with mantle, is much more efficient than the ordinary burner for kerosene, about doubling the number of candle power hours per gallon. But unless very careful attention is given to the condition and operation of this burner the benefits will not be obtained and there is great liability to have immense quantities of sooty smoke produced.

4. The Canchester burner, Argand with carbon-cylinder wick-top, and mantle, is the most efficient kerosene burner found, giving nearly five times the candle power hours per gallon given by a 1½ inch flat wick common burner, and a greatly better quality of light. And the Canchester is not at all troublesome to use.

5. All kerosene lights without mantle are of very poor *quality*, very unlike daylight, hard on the eyes, and hence likely to produce pain and nervous irritation and injury to health.

6. Acetylene, gasoline, and alcohol (the first one a naked flame and the last two using mantles) give light of a very much better *quality* than kerosene, a light which in the proportions of the colors in its composition is very much more like daylight. A light of good quality can be obtained, also, from kerosene, by using a mantle, as in the Canchester burner.

7. By reason of the very excellent *quality* of acetylene light, and taking account of the eye injuries and pain and the effects on general health that may result from the use of ordinary kerosene light, the former may be truly much more economical than the latter, notwithstanding the greater cost per candle power of acetylene. This is true, also, of alcohol light (even at present prices), by reason of its very good quality.

With the increasing education of farmers' children, and the increasing intellectual and social life in farm homes, the use of artificial light in farm houses is increasing, and the money economy, but more the sanitary economy of artificial lighting is of increasing importance. Nor may the aesthetic element, the effect on life of attractive lighting, be left unconsidered.

William [illegible]

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The Pennsylvania State College Agricultural Experiment Station

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BULLETIN No. 104

THE RESPIRATION CALORIMETER

AT THE

INSTITUTE OF ANIMAL NUTRITION OF THE PENNSYLVANIA STATE COLLEGE

By HENRY PRENTISS ARMSBY

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
OCTOBER, 1910

AGRICULTURAL EXPERIMENT STATION
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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 104

THE RESPIRATION CALORIMETER

AT THE

Institute of Animal Nutrition of the Pennsylvania State College

By HARRY PRENTISS ARMSBY

One important method of studying the problems of nutrition is the so-called balance experiment, in which the income of matter or of energy, or both, in the food is compared with the outgo in the various excreta and in the heat evolved.

So far as the visible excreta are concerned, such a comparison involves no special technical difficulties, but if it is to be extended to the gaseous excreta and the heat, special forms of apparatus are necessary.

Numerous forms of respiration apparatus have been constructed in the past permitting of very exact determinations of the gaseous exchange, but not until quite recently has it been possible to combine with a determination of the respiratory products a direct measurement of the heat evolved by man or by the larger domestic animals. The first successful apparatus of this sort was that constructed by Atwater and Rosa* for experiments upon man and called by them the respiration calorimeter. In 1898, the construction of a similar apparatus for experiments upon cattle was undertaken by this institution in co-operation with the Bureau of Animal Industry of the United States Department of Agriculture and the first experiments with it were made in the winter of 1901-02, constituting, so far as the writer is aware, the first direct determinations of the heat production of cattle.

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* U. S. Dept. of Agr., Office of Experiment Stations, Bulletins 63 and 136.

The general plan of the apparatus is substantially the same as that of the original* Atwater-Rosa respiration calorimeter; that is, it is a Pettenkofer respiration apparatus, the chamber of which serves also as a calorimeter.

The Respiration Apparatus.

The respiration chamber of the Pennsylvania apparatus, constructed of sheet copper, is 1.83 meters wide, 3.15 meters long and 2.44 meters high. A platform 53 centimeters above the base of the chamber carries the stall in which the animal stands. Beneath the rear portion of this stall is a small chamber of sheet copper about 86 by 170 by 45 centimeters, entirely shut off from the rest of the respiration chamber except for two holes through the platform, and having a separate air-tight door. Through one of the holes mentioned, a rubber tube leads from the urine funnel to a receptacle of tinned copper; to the other hole is attached a large rubber duct covering the hind quarters of the animal, and underneath it is placed a galvanized-iron box, tightly pressed against the lower side of the platform, to receive the droppings of the animal. This small chamber, therefore, has only such air connection with the remainder of the chamber as is unavoidable through the openings around the two ducts, but is in thermal communication with it through its copper walls. The operation of opening the air-tight door, removing the excreta and replacing the receptacles occupies not more than a minute or two, and it is assumed that any error thus introduced is insignificant.

At the other end of the platform is the feed box. This is provided with an air-tight cover, which can be opened or closed by means of a lever operated from outside, and is also provided with an air-tight door. By lowering the cover the feed box can be entirely shut off from the chamber. The air-tight door can then be opened for the introduction of feed or the removal of residues, the door closed, and the lid again lifted. The arrangemeent constitutes, in brief, an air-lock and is substantially like that employed in the respiration apparatus of the Moeckern Experiment Station. The water supply is introduced into a small drinking basin at the side of the feed box by means of a pipe carried through the calorimeter wall, the water being weighed in and any excess removed by drawing the water in the pipe down to a fixed level.

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* The respiratory portion of their apparatus has subsequently been converted into a Regnault, or closed circuit, apparatus. See publication No. 42 of the Carnegie Institution of Washington, D. C.

The large door at the rear of the apparatus through which the animal enters and the two small doors giving access, respectively, to the feed box and excreta have heavy oak frames and are made tight by means of gaskets composed of rubber tubing, the doors being kept in place by means of pressure catches such as are frequently used on large refrigerators.

Through the chamber just described a current of outdoor air is aspirated by means of a special pump, the air first passing over the expansion coils of an ice machine, where most of its moisture is deposited as frost. At the point of entry to the chamber, samples are taken alternately by one or the other of two large aspirators of constant flow at the rate of 200 liters in twelve hours. In these samples moisture and carbon dioxid are determined by passing them through U tubes containing sulphuric acid and soda lime.

From the chamber the air passes to the meter pump, which serves both to maintain the air current and to measure and sample it. The meter pump, which was designed and built especially for this apparatus by Mr. Frederick Hart, of Poughkeepsie, N. Y., acts upon the same principle as the Blakeslee pump used in the Atwater-Rosa apparatus,but differs materially from it in mechanical details. A full description of it has been published*. The pump consists essentially of two cylinders of drawn-steel tubing, 48.3 centimeters in diameter, moving up and down in mercury. The pump is adjustable to three different lengths of stroke and four speeds. As thus far used, it has been set to deliver approximately 50 liters per stroke (exactly, 49.539) and has been run at the rate of about 14 strokes per minute, the total ventilation, therefore, being about 700 liters per minute. The number of strokes as recorded by a revolution counter, with the corrections for temperature and pressure, gives the total volume of air passing through the apparatus, and the results of the analysis of the ingoing air, calculated upon this volume, give the weights of water and carbon dioxid carried into the apparatus by the current of air.

By means of a shunt valve connected with an ingenious train of gearing one stroke is delivered at regular intervals alternately through one or the other of two special outlets. The pump can be set to deliver thus one stroke in 200, one in 400, or one in 800. The two aliquot samples thus taken are conducted to two large pans having counterpoised rubber covers substantially like those used in the Atwater-Rosa apparatus. From these pans each sample separately is aspirated by means of a subsidiary air pump and after bubbling through concentrated sulphuric acid contained in a gas washing bottle passes through a set of six large U tubes (27 centimeters), the first two containing pumice stone saturated with sulphuric acid, the second two soda lime, and the last two pumice stone and sulphuric acid. The increase in weight of the flask and the first two tubes gives the amount of water and that of the remaining four tubes the amount of carbon dioxid contained in the samples, and these amounts multiplied by the proper factor give the total amounts contained in the outcoming air. Subtracting those contained in the ingoing air, determined as described, gives the amount added by the animal. Since 1906, the composition of the outcoming air has also been determined in samples taken by means of large aspirators (800 liters) of constant flow.

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* American Machinist, 25 (1902), p. 1297.

From the U tubes the air is conducted to the apparatus for determining the combustible gases excreted. This consists of a copper tube 2.5 centimeters in diameter and having an effective length of about 150 centimeters, filled with platinized kaolin and kept at a red heat by an electric furnace. In this tube the combustible gases are oxidized to carbon dioxid and water, which are absorbed and weighed in a second set of U tubes similar to the first. Many difficulties were experienced in securing satisfactory results with this part of the apparatus on account of the large volume of air to be handled (3½ liters per minute as ordinarily used) and the considerable force required to draw the air through the numerous absorption tubes. The connections with the combustion tubes are made with soldered joints, and the absorption tubes are carefully tested with a manometer before being used. The amount of platinized kaolin employed has been demonstrated to be sufficient to oxidize much larger amounts of methan than it will ever be required to in actual use.

No parallel determinations of combustible gases are at present made in the air entering the apparatus. The amounts have been shown to be very small in this locality and corrections are made for them from the results of numerous blanks.

The Calorimeter.

The arrangements for determining the heat given off by the animal are in all essentials like those of the Atwater-Rosa apparatus. The heat is absorbed by a current of cold water passing through copper pipes at the top of the respiration chamber, access of air to these pipes being regulated by means of shields which can be raised or lowered by the operator. The temperature of the ingoing and outcoming water is read every four minutes by means of two mercurial thermometers, graduated to $\frac{1}{50}$°C. and carefully calibrated. The volume of water passing through is measured by means of two copper meters, each containing 100 liters. The apparatus is so arranged that the weight of the heat absorbers may be taken from outside, any condensation of moisture upon them being thus indicated.

The respiration chamber proper of the apparatus is a metallic chamber of the dimensions stated. Surrounding this, with an air space of about 10 centimeters between, is a double wooden wall, which in turn is surrounded by an air space of 10 centimeters and a second wall. The walls of the respiration chamber proper are double, the inner of copper and the outer of zinc, with a dead air space of 7.6 centimeters between, and through these walls are distributed some 600 iron German-silver couples, connected in series with a reflecting galvanometer and serving to indicate any difference in temperature between the inner (copper) and outer (zinc) surface. Any such difference is rectified and the walls of the chamber maintained adiabatic by heating or cooling the air space surrounding the zinc wall—the former by means of an electric current through resistance wires and the latter by circulating cold water through brass pipes. The double wall surrounding the metallic chamber also contains a smaller number of iron German-silver couples, and is in its turn kept nearly adiabatic by regulating the temperature of the second air space. By means of very similar devices the temperature of the ingoing air is maintained the same as that of the outcoming air.

The temperature of the interior of the apparatus is measured by means of a series of copper resistance thermometers connected to a slide wire Wheatstone bridge, and also by means of two mercurial thermometers. By raising or lowering the shields or varying the flow of water through the absorbers the rate at which heat is removed through the water current may be so regulated as to keep the temperature of the interior constant within very small limits, while the slight variations are made to balance each other in the course of an experiment, so that there is practically no capacity correction. Under these conditions, all the heat evolved by the animal must leave the apparatus either as sensible heat in the water current or as the latent heat of water vapor.

In practice, of course, corrections have to be made for any heat introduced or removed as sensible heat in the feed, excreta, etc. The friction of the water in the coil of copper pipes is also the source of a minute amount of heat, which is computed from the volume of water and the fall in pressure in passing through the pipes. This difference in pressure also affects slightly the readings of the thermometers, tending to make those in the ingoing water relatively higher than those in the outcoming water. The small correction for this difference has been determined experimentally within the range of pressures used.

To the heat determined in the manner thus described, there must be added the latent heat of evaporation of the water vaporized in the respiration chamber and brought out in the air current. This is computed from the results for water, the latent heat of evaporation at 18°C. being taken as 0.587 Calories per gram, as determined by Smith*.

The Building.

The building in which the apparatus is housed is of brick, with heavy walls containing an air space to aid in maintaining uniform temperature. The floor is of concrete, and the ceiling high enough to leave fully one meter clear space above the top of the respiration chamber, which stands upon three brick piers about 45 centimeters above the floor of the room. In this way any difficulty arising from differences in temperature at different points in the room has been avoided.

Method of Experiments.

The experiments thus far made have been of forty-eight hours' duration, this period being divided into subperiods of twelve hours each. The animal is placed in the apparatus five or six hours before the beginning of the experiment, which has been conveniently placed at 6 p. m. By this time the apparatus has come into equilibrium and it is only necessary to shift the current of air from one set of absorption apparatus to another in order to begin the experiment.

The experiments have followed each other at an averge interval of from two to three weeks. During the intervening time the animal stands in an adjoining room in a stall which is provided with appliances for the quantitative collection of the visible excreta. An actual experiment requires the services of at least seven men, exclusive of the assistant in charge of the feeding and the collection of excreta.

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* Physical Review, 25, 170.

Check Tests.

The accuracy of a complicated apparatus like the respiration calorimeter can, of course, be satisfactorily determined only by actual test. Our check tests have been made by burning known amounts of ethyl alcohol in the respiration chamber and measuring the amounts of carbon dioxid, water and heat evolved precisely as in an animal experiment.

So-called "absolute" alcohol was diluted with about 10 per cent. of distilled water and the amount of anhydrous alcohol contained in the mixture computed from the specific gravity as determined by a Squibb's 50 c. c. pyknometer at 15.6°C. The alcohol was burned in an Argand lamp into which it was fed from outside the chamber by a device which maintained a constant level in the lamp. This lamp was burned for at least 2 preliminary hours during which regular ventilation of the chamber was maintained and the heat removed by the water current as fast as produced. Only when everything was in equilibrium was the actual experiment begun. Except in the tests of January 12 and May 8, 1906, in which Atwater & Benedict's average of 7.067 Cals. per gram was used, the heat of combustion of the alcohol used was determined by means of the bomb calorimeter and ranged from 7.131 to 7.184 Cals. per gram of anhydrous alcohol. These figures are materially higher than the average used by Atwater & Benedict.

Up to the end of the year 1908-09, there have been made in all eighteen alcohol check experiments, excluding those made on January 7, 1907, and April 29, 1908, which seemed clearly erroneous*.

The following two tables contain the results of these eighteen check tests divided into two groups. The first group includes those made with the original form of the apparatus in which a considerable portion of the moisture of the outgoing air was condensed in copper freezing cans, while the second group includes the tests made with the apparatus as described on previous pages.

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* In the first of these two tests, less than 90 per cent. of the water produced was recovered, but notwithstanding this the heat found was much too high. In the second of the two tests, the results for carbon dioxid and water were both much too low. Since in general the results for carbon dioxid are very accurate and those for water tend to be too high, we have felt justified in rejecting these two check tests.

Results of Alcohol Check Tests.

DATE	Number of Hours	Weight of Alcohol		WATER					CARBON DIOXID				
				Computed Grms.	Results by Meter Pump		Results by Aspirator		Computed Grms.	Results by Meter Pump		Results by Aspirator	
		Hydrated Grms.	Anhydrous Grms.		Observed Grms.	Percentage Observed	Observed Grms.	Percentage Observed		Observed Grms.	Percentage Observed	Observed Grms.	Percentage Observed
USING COPPER FREEZING CANS													
January 16, 1902	6	564.85	511.41	653.68	689.61	105.5			977.30	963.15	98.5		
January 29, 1902	6	592.86	536.77	686.10	767.50	111.9			1025.77	1017.86	99.2		
April 29, 1902	11	972.68	876.74	1125.04	1296.43	115.2			1675.30	1665.14	99.4		
January 20, 1903	6	527.67	475.62	610.28	629.42	103.1			908.91	891.58	98.1		
March 26, 1903	6	526.53	474.60	608.98	687.97	112.9			906.96	891.24	98.3		
April 28, 1903	6	503.16	453.53	581.94	676.90	116.3			866.69	855.73	98.7		
January 5, 1904	6	487.12	436.89	563.01	633.97	112.6			834.90	830.58	99.5		
March 25, 1904	7	541.68	485.82	626.07	675.83	107.9			928.40	907.51	97.7		
December 13, 1904	6	506.92	455.90	586.11	635.23	108.4			871.22	839.19	96.3		
February 10-11, 1905	12	1238.58	1111.78	1431.70	1515.88	105.9			2124.61	2148.15	101.1		
May 9, 1905	10	939.94	843.73	1086.50	1211.84	111.5			1612.37	1597.93	99.1		
January 12, 1906	8	750.76	671.07	867.32	890.72	102.7			1282.41	1278.49	99.7		
Totals		8152.75	7333.86	9426.73	10311.30				14014.84	13886.55			
Averages		677.73	611.16	785.56	859.28	109.38			1167.90	1157.21	99.08		
WITHOUT COPPER FREEZING CANS													
May 8, 1906	7.5	702.81	628.21	812.68	846.62	104.18	821.85	101.13	1200.50	1187.79	98.94	1197.72	99.76
January 15, 1907	7	621.73	555.73	720.17	792.18	110.00	743.47	103.24	1062.01	1050.79	98.94	1059.59	99.77
May 3, 1907	8	706.23	627.68	815.26	922.88	113.20	833.63	102.25	1199.50	1198.82	99.94	1201.46	100.16
November 12, 1907	9	809.95	716.98	931.23	960.04	103.1	886.50	95.2	1370.14	1363.68	99.53	1368.91	99.92
November 17, 1908	8	676.40	601.17	780.82	866.18	110.9	829.00	106.2	1148.89	1138.04	99.0	1146.18	99.8
April 15, 1909	8	666.89	593.76	770.02	807.19	104.8	725.38	94.2	1134.73	1121.89	98.9	1131.32	99.7
Totals		4184.01	3723.53	4830.18	5195.09		4839.83		7115.77	7061.01		7105.18	
Averages		697.34	620.59	805.03	865.85	107.55	806.64	100.20	1185.96	1176.83	99.23	1184.20	99.85
BOTH SERIES													
Totals		12336.76	11057.39	14256.91	15506.39		4839.83		21130.61	20947.56		7105.18	
Averages		685.38	614.30	792.05	861.47	108.76	806.64	100.2	1173.92	1163.73	99.13	1184.20	99.85

Results of Alcohol Check Tests—Cont.

DATE	Number of Hours	Weight of Alcohol		HEAT						
				Computed Cals.	Results by Meter Pump		Results by Aspirator		Results Corrected for Excess of Water	
		Hydrated Grms.	Anhydrous Grms.		Observed Cals.	Percentage Observed	Observed Cals.	Percentage Observed	Observed Cals.	Percentage Observed
USING COPPER FREEZING CANS										
January 16, 1902	6	564.85	511.41	3647.78	3743.82	102.6			3722.55	102.05
January 29, 1902	6	592.86	536.77	3828.67	3862.08	100.9			3813.89	99.61
April 29, 1902	11	972.68	876.74	6298.50	6346.62	100.7			6245.16	99.17
January 20, 1903	6	527.67	475.62	3417.09	3427.16	100.3			3415.83	99.96
March 26, 1903	6	526.53	474.60	3409.76	3407.01	99.9			3360.25	98.55
April 28, 1903	6	503.16	453.53	3258.38	3190.31	97.9			3134.09	96.19
January 5, 1904	6	487.12	436.89	3125.29	3142.76	100.6			3100.75	99.21
March 25, 1904	7	541.68	485.82	3475.31	3549.00	102.1			3519.52	101.27
December 13, 1904	6	506.92	455.90	3251.05	3308.19	101.8			3279.11	100.9
February 10-11, 1905	12	1238.58	1111.78	7928.28	8031.60	101.3			7981.77	100.7
May 9, 1905	10	939.94	843.73	6016.70	6090.58	101.2			6016.78	100.0
January 12, 1906	8	750.76	671.07	4785.45	4826.07	100.9			4812.22	100.56
Totals		8152.75	7333.86	52442.26	52925.20				52401.92	
Averages		677.73	611.16	4370.19	4410.43	100.92			4366.83	99.92
WITHOUT COPPER FREEZING CANS										
May 8, 1906	7.5	702.81	628.21	4479.78	4523.89	100.98	4509.23	100.65	4503.80	100.53
January 15, 1907	7	621.73	555.73	3962.98	4025.53	101.58	3996.67	100.87	3982.90	100.51
May 3, 1907	8	706.23	627.68	4476.05	4559.31	101.87	4506.48	100.68	4495.60	100.43
November 12, 1907	9	809.95	716.98	5112.81	5137.65	100.5	5094.48	99.6	5120.74	100.10
November 17, 1908	8	676.40	601.17	4286.98	4310.68	100.6	4288.85	100.05	4260.57	99.40
April 15, 1909	8	666.89	593.76	4234.12	4241.08	100.1	4193.06	99.0	4219.26	99.70
Totals		4184.01	3723.53	26552.73	26798.14		26588.77		26582.87	
Averages		697.34	620.59	4425.46	4466.36	100.92	4431.46	100.14	4430.48	100.11
BOTH SERIES										
Totals		12336.76	11057.39	78994.99	79723.36		26588.77		78984.79	
Averages		685.38	614.30	4388.61	4429.07	100.92	4431.46	100.14	4388.04	99.99

Summary of Results of Alcohol Check Tests.

	Results with Samples taken by Meter Pump	Results with Samples taken by Aspirator
Using copper freezing cans		
Carbon dioxid		
Average percentage recovered	99.1	
Range of single results	2.4	
Water		
Average percentage recovered	109.4	
Range of single results	6.8	
Heat		
Average percentage recovered	100.9	
Range of single results	2.4	
Without copper freezing cans		
Carbon dioxid		
Average percentage recovered	99.2	99.9
Range of single results	0.5	0.2
Water		
Average percentage recovered	107.6	100.2
Range of single results	5.1	6.0
Heat		
Average percentage recovered	100.9	100.1
Range of single experiments	0.9	0.9

The last two columns of the first table show the heat production corrected for the apparent error in the water determination. These results are obtained by adding to the heat as measured directly in the water current the latent heat of evaporation corresponding to the computed amount of water formed from the alcohol burned. On the average, these results for heat agree very closely with the theoretical, the percentages recovered and the corresponding range of single results being:

With freezing cans	99.92	2.93*
Without freezing cans	100.11	0.57
Average of all	99.99	2.93*

Apparently the most serious error in the heat determinations lies in the measurement of the water vapor given off, and the more accurate determination of the latter by means of the aspirator samples reduces the average error to a very small amount, although it does not seem to materially reduce the range of the single results. The removal of the copper freezing cans appears not to have affected the average accuracy of the determinations. That the range of the single results is reduced may be due in part to increased experience in the use of the apparatus.

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* The omission of 1 result reduces this to 1.75.

Our earlier experiments on animals were made with the old form of apparatus which, in the alcohol check tests, gave uniformly too high results for water. The effect of this, as already noted, is to make the results for heat also too high, but the error in animal experiments is relatively smaller, first because it affects only the amount estimated for the latent heat of water vapor, which constitutes only about one-fourth of the total heat measured, and second because the error appears to affect chiefly the first few hours of an experiment and is therefore far less serious in an animal experiment extending over 48 hours than in an alcohol check test lasting for but six to twelve hours.

The excess of water vapor found in the samples taken by the meter pump seems to be due to a drying out of the sampling pans and especially of their rubber covers during the earlier hours of the experiment. The meter pump takes a sample of $\frac{1}{200}$ of the total outgoing air. A comparatively small amount of residual moisture in the pans at the beginning of an experiment multiplied by the factor 200 will evidently cause a considerable error in the relatively short alcohol check experiment, while the effect on a long experiment would be inconsiderable.

That such is actually the case is shown by the results of those experiments upon animals in which results with the meter pump and with the aspirator samples can be compared. Such of these results as are now available are contained in the following table, the experiments being designated by their numbers simply.

The error due to the evaporation of water from the pans would naturally affect principally or entirely the first subperiod of 12 hours and this is precisely what seems to have occurred. In Experiment No. 208 there is an excess of water in the first subperiod as determined by the meter pump in every case, and in Experiment No. 207, there is a similar excess in five cases out of eight, while there is no such difference in the results for carbon dioxid. The average excess of water found by the meter pump over that found by the aspirator in the first subperiod, omitting negative results, is 61.8 grams, or including all the negative results, 43.8 grams. In the remaining subperiods the excess of water found by the meter pump over that found

Comparison of Results with Meter Pump and Aspirator in Experiments on Animals.

EXPERIMENT No. 207

Animal	Period	Sub-period	Water			Carbon Dioxid.		
			By Meter Pump	By Aspirator	Excess by Meter Pump	By Meter Pump	By Aspirator	Excess by Meter Pump
A	I	1	1816.2	1792.1	+ 24.1	2178.7	2173.0	+ 5.7
		2	1797.1	1804.1	– 7.0	2171.7	2167.1	+ 4.6
		3	2021.2	2008.9	+ 12.3	2188.6	2174.6	+ 14.0
		4	1905.9	1908.7	– 2.8	2177.8	2186.5	– 8.7
B	I	1	1830.9	1843.8	– 12.9	1935.0	1948.3	– 13.3
		2	1867.0	1858.4	+ 8.6	1984.2	1993.1	– 8.9
		3	1817.8	1861.9	– 44.1	1913.7	1968.6	– 54.9
		4	1838.0	1838.8	– 0.8	1970.5	1972.9	– 2.4
A	II	1	3469.7	3534.2	– 64.5	3114.6	3138.6	– 24.0
		2	3627.9	3631.4	– 3.5	3193.8	3169.3	+ 24.5
		3	3719.8	3737.4	– 17.6	3150.9	3180.0	– 29.1
		4	3351.4	3359.3	– 7.9	3089.6	3106.0	– 16.4
B	II	1	3074.6	3117.8	– 43.2	2396.3	2420.7	– 24.4
		2	2982.8	2998.8	– 16.0	2444.9	2457.3	– 12.4
		3	3244.7	3240.1	+ 4.6	2427.6	2423.4	+ 4.2
		4	3139.2	3154.4	– 15.2	2510.8	2511.1	– 0.3
A	III	1	1559.2	1486.9	+ 72.3	1558.2	1571.4	– 13.2
		2	1412.3	1407.9	+ 4.4	1548.7	1565.7	– 17.0
		3	1433.2	1437.0	– 3.8	1534.4	1535.2	– 0.8
		4	1434.7	1428.7	+ 6.0	1533.0	1537.0	– 4.0
B	III	1	1828.6	1764.6	+ 64.0	1543.0	1551.2	– 8.2
		2	1721.2	1723.7	– 2.5	1532.1	1552.7	– 20.6
		3	1799.7	1788.4	+ 11.3	1519.3	1521.5	– 2.2
		4	1715.7	1708.8	+ 6.9	1526.9	1532.4	– 5.5
A	IV	1	2049.5	1988.6	+ 60.9	2004.2	2018.8	– 14.6
		2	1951.5	1940.4	+ 11.1	2033.4	2039.7	– 6.3
		3	2062.8	2059.2	+ 3.6	2032.9	2038.7	– 5.8
		4	1992.4	1994.4	– 2.0	2023.7	2031.6	– 7.9
B	IV	1	2300.2	2257.8	+ 42.4	1952.8	1964.9	– 12.1
		2	2146.6	2136.1	+ 10.5	1990.6	1985.8	+ 4.8
		3	2412.3	2429.4	– 17.1	1939.2	1949.8	– 10.6
		4	2519.1	2532.2	– 13.1	1973.3	1986.5	– 13.2

by the aspirator is positive in 27 cases and negative in 24 cases, the average algebraic differences being:—

In Experiment 207, ... – 3.1 grams.
In Experiment 208, ... + 1.4 grams.
Average of all, ... – 0.7 grams.

Comparison of Results with Meter Pump and Aspirator in Experiments on Animals

EXPERIMENT No. 208

Animal	Period	Sub-period	Water			Carbon Dioxid.		
			By Meter Pump	By Aspirator	Excess by Meter Pump	By Meter Pump	By Aspirator	Excess by Meter Pump
E	I	1	1565.8	1509.6	+ 56.2	1460.2	1458.4	+ 1.8
		2	1376.1	1384.4	− 8.3	1472.2	1485.8	− 13.6
		3	1413.2	1391.5	+ 21.7	1439.3	1441.7	− 2.4
		4	1304.6	1317.7	− 13.1	1476.0	1477.3	− 1.3
E	II	1	1058.3	983.7	+ 74.6	1048.8	1063.4	− 14.6
		2	968.7	964.4	+ 4.3	1063.5	1059.3	+ 4.2
		3	953.8	946.5	+ 7.3	1035.0	1031.1	+ 3.9
		4	963.1	973.7	− 10.6	1102.9	1112.9	− 10.0
E	III	1	901.2	863.4	+ 37.8	874.3	889.3	− 15.0
		2	838.8	831.4	+ 7.4	894.0	901.0	− 7.0
		3	890.2	889.5	+ 0.7	895.4	897.5	− 2.1
		4	838.2	842.7	− 4.5	888.3	895.9	− 7.6
E	IV	1	1812.8	1769.7	+ 43.1	1578.7	1593.5	− 14.8
		2	1615.7	1630.9	− 15.2	1563.4	1544.8	+ 18.6
		3	1709.3	1700.7	+ 8.6	1486.8	1492.5	− 5.7
		4	1487.8	1499.4	− 11.6	1508.6	1528.0	− 19.4
E	V	1	1209.8	1134.1	+ 75.7	1090.8	1103.6	− 12.8
		2	1066.8	1051.7	+ 15.1	1091.1	1099.2	− 8.1
		3	1095.3	1093.4	+ 1.9	1084.7	1091.1	− 6.4
		4	1036.3	1044.5	− 8.2	1095.5	1103.9	− 8.4
E	VI	1	960.2	906.6	+ 53.6	847.9	859.6	− 11.7
		2	835.4	815.5	+ 19.9	823.1	826.9	− 3.8
		3	857.2	832.0	+ 25.2	829.2	819.8	+ 9.4
		4	774.6	774.3	+ 0.3	819.8	825.1	− 5.3
D	I	1	1405.7	1283.0	+122.7	978.6	991.8	− 13.2
		2	1402.0	1383.8	+ 18.2	955.2	955.9	− 0.7
		3	1226.1	1221.1	+ 5.0	948.0	957.7	− 9.7
		4	1400.1	1419.4	− 19.3	983.9	991.3	− 7.4
D	II	1	984.2	925.8	+ 58.4	732.4	737.5	− 5.1
		2	897.8	888.5	+ 9.3	746.5	752.3	− 5.8
		3	858.1	851.3	+ 6.8	723.1	726.7	− 3.6
		4	797.9	801.3	− 3.4	716.9	723.2	− 6.3
C	II	1	1401.4	1322.6	+ 78.8	1287.9	1298.6	− 10.7
		2	1247.3	1236.7	+ 10.6	1286.1	1288.4	− 2.3
		3	1354.1	1346.2	+ 7.9	1341.3	1338.5	+ 2.8
		4	1526.9	1559.6	− 32.7	1442.7	1451.7	− 9.0

In the later alcohol check tests previously tabulated, which are all short, corresponding in this respect to the first subperiods of the animal experiments, the average difference between the water vapor as determined by the meter pump and that determined by the aspirator was 59.2 grams, an amount agreeing well with the average excess found in the first subperiods of the animal experiments.

In the light of the foregoing results and discussion, we feel justified in concluding that the results of a single experiment with the respiration calorimeter may be regarded as accurate to within approximately the following percentages of the total amounts determined:

Carbon dioxid	0.5 per cent.
Water (in aspirator samples)	6.0 per cent.
Heat,	1.0 per cent.

Sci 1638.5.4

The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 105

INFLUENCE OF TYPE AND OF AGE UPON THE UTILIZATION OF FEED BY CATTLE

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
NOVEMBER, 1910

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 105

INFLUENCE OF TYPE AND OF AGE UPON THE UTILIZATION OF FEED BY CATTLE

—by—

HENRY PRENTISS ARMSBY AND J. AUGUST FRIES

In a permanent system of agriculture, the essential function of domestic animals is to utilize for the benefit of man the solar energy stored in the inedible products of the soil, such as hay, straw, and other forage crops, or in the host of by-products arising in the preparation of farm crops for use as human food. When these inedible substances are consumed by domestic animals a portion of this energy is recovered, in part as work but largely in the form of materials serving for the nutrition of man.

The Institute of Animal Nutrition of The Pennsylvania State College, in co-operation with the Pennsylvania Experiment Station and with the Bureau of Animal Industry of the United States Department of Agriculture, is engaged in a study of those scientific principles which underlie and condition the successful economic transformation by the animal of waste products into human food. The investigations in progress relate to three general classes of questions:

First: How do different feeding stuffs compare with each other as to their content of energy and the proportion of it which may be rendered available to man through the agency of domestic animals?

Second: What is the relative efficiency of different types of animals as converters of waste energy into forms suitable for human food?

Third: How do the various conditions under which animals may be kept affect their efficiency as producers of human food?

The experiments here recorded relate chiefly to the second class of problems above mentioned, viz., the influence of the type of animal, their special subject being a comparison as meat producers of the beef type of animal with the so-called "scrub," that is, with an animal of mixed and unknown breeding but partaking of the dairy type. Practical experience has shown that there is a distinct financial advantage on the side of the specific beef type of steer, but considerable diversity of opinion exists as to the real reasons for this difference.

Description of Experiments.

Two steer calves were selected as the subjects of investigation. One of these was a pure bred Aberdeen-Angus of typical beef form, while the other was a "scrub" containing considerable Jersey blood and possessing the dairy rather than the beef form. These animals were about 8½ and 11 months old respectively at the beginning of the investigation in October, 1904, and were under nearly continuous observation for over 2½ years. During this time, with the exception of certain of the periods in which the balance of matter and energy was determined by means of the respiration calorimeter, they were fed an ordinary growing ration and while maintained in a thrifty condition were not fattened. The feeding stuffs used in each period were of the same kind for both animals and the different grains fed were mixed throughout in the same proportions for each steer. The live weights of the animals were taken at least weekly, as well as on three consecutive days at the end of each month, and they were systematically measured and photographed every three months. The accompanying photographs of the animals on three different dates will serve better than words to illustrate the character of the animals used. The measurements show that the "scrub" increased more rapidly in length and height than did the pure bred animal, the gain of the latter being more largely due to increase in size of body.

At intervals, the digestibility of the total ration and the nitrogen balance were determined for each animal. It was originally intended to make these determinations once in three months, but this proved to be impracticable. In all, four such trials were made in addition to those included in the respiration calorimeter experiments mentioned in the next paragraph, viz., in December, 1904, July, 1905, November, 1905, and June, 1906.

During each of the three winters covered by the investigation, four experiments were made on each animal by means of the respiration calorimeter in order to determine the percentage availability of the energy of the feeds consumed. During the first winter, that of 1905, the feeding stuffs used differed from those employed during the ordinary feeding. In the succeeding two winters, the grain feeds used were the same, only the amounts differing. The respiration calorimeter experiments, of course, included determinations of the digestibility of the rations and of the nitrogen balances of the animals.

Digestive Capacity.

The assertion is often heard that the typical beef animal has a greater digestive capacity than the scrub. What is really meant by this assertion in most cases is that the former has a greater power of assimilation. If we use the word digestive in the strict sense as referring to the percentages of the several nutrients consumed which are resorbed from the digestive tract and taken up into the blood, the idea that there are important individual differences among animals in this respect has not been borne out by experiments in the past and is not supported by these investigations.

Digestibility of Hay.—The results of the several digestion experiments may be most simply compared on the basis of the percentage of digestibility of the total dry matter, the total energy and the protein. Table 1 shows the average percentage digestibility of these ingredients of the hay fed in each of three years covered by the investigation, the figures being in each case the average of two trials.

Table 1.—Average Percentage Digestibility of Timothy Hay.

	Pure-bred Steer %	Scrub Steer %
1905		
Total dry matter	52.8	54.9
Energy	49.5	50.8
Protein	14.4	3.0
1906		
Total dry matter	53.7	55.3
Energy	50.7	52.6
Protein	34.1	33.8
1907		
Total dry matter	62.0	61.4
Energy	58.6	57.9
Protein	43.8	43.6

The differences between the two animals shown by the foregoing table are so small as to be scarcely significant, but if anything seem rather in favor of the scrub animal, especially during the first two years. At any rate the figures give no evidence of the possession of any higher digestive power by the pure bred animal.

Digestibility of Grain.—The digestiblity of the grain was determined in the usual way by a difference computation. The results as between the two trials made in each year were somewhat fluctuating, although the differences were not larger than might be expected. The average results for the digestibility of the grain are shown in Table 2.

Table 2.—Average Percentage Digestibility of Grain.

	Pure-bred Steer %	Scrub Steer %
1905—Bran		
Total dry matter	66.1	66.5
Energy	67.5	69.1
Protein	72.7	81.4
1906—Mixed Grain		
Total dry matter	81.4	80.4
Energy	82.3	81.9
Protein	72.6	76.0
1907—Mixed Grain		
Total dry matter	77.8	78.8
Energy	78.9	79.7
Protein	73.4	80.3

The foregoing results lend no support to the supposed greater digestive capacity of the pure-bred animal.

Metabolizable Energy.

Feed may be regarded as the fuel of the animal body, supplying energy for its operation much as coal or other fuel does for those of the engine. The feed of domestic animals, however, is very incompletely oxidized in the body, much of its potential energy escaping unused in the unburned matter excreted in the feces and urine, and in the gaseous products of fermentation, especially methan. It is clear that only that portion of the total energy remaining after the subtraction of the amount carried off in the excreta can possibly be of use to the body. This portion of the total energy has been called by the writers metabolizable energy, the term signifying that portion of the total energy which can be converted into the kinetic form in the body. It is equivalent to the energy of the feed minus the energy of the excreta. The term fuel values has also sometimes been employed for it because it is equivalent to the total amount of heat capable of being produced in the body by the oxidation of the feed.

In these investigations, the determinations of the energy of feces, urine and methan in the respiration calorimeter experiments afford the basis for comparing the percentage of the total energy of the feeding stuffs which was metabolized by the two animals, the average results being as follows:

Table 3.—Average Percentage of Feed Energy Metabolizable.

	Per Cent. of Total Energy		Per Cent. of Energy of Digested Organic Matter	
	Pure-bred Steer	Scrub Steer	Pure-bred Steer	Scrub Steer
Timothy Hay				
1905	39.52	40.70	79.91	80.07
1906	40.52	41.88	79.88	79.57
1907	46.14	45.11	78.75	77.92
Average of 3 years	42.06	42.56	79.51	79.19
Wheat Bran				
1905	55.01	55.99	81.53	80.97
Mixed Grain				
1906	67.47	66.64	81.99	81.41
1907	64.49	62.98	81.73	78.95
Average of 2 years	65.98	64.81	81.81	80.18

Aside from an apparent slight inferiority of the scrub steer as regards the mixed grain in the experiments of 1907, which arises from an exceptionally low result in one of the trials, the foregoing figures fail to indicate any material difference in the percentage of the total energy of the feed which the two animals were able to metabolize.

Availability of Metabolizable Energy.

The metabolizable energy of a feeding stuff is that portion of its total potential energy which is capable of conversion into the kinetic form in the body. It corresponds to the conception of "Physiologischer Wärmewert", or "Physiologischer Nutzeffeckt" introduced by Rubner* in connection with his experiments upon the replacement values of nutrients, or to the fuel values of Atwater**. Upon the results of his earlier experiments, Rubner based his celebrated law of isodynamic replacement. This law is in effect that, when fed in limited quantities, the several nutrients may be substituted as sources of energy for body substance previously katabolized, or may replace each other, in amounts inversely proportional to their physiological heat values, i. e., their metabolizable energy. The validity of this law has been generally accepted and not only have the relative values of single nutrients and of human dietaries been estimated upon the basis of their metabolizable energy, but it has been attempted also to apply Rubner's factors to the digestible protein, carbohydrates and fats, so-called, of stock feeds and extensive tables of the fuel values of the latter computed in this way have been published. Moreover, there has been a natural tendency to overlook the limitation which Rubner set to his law and to apply it to productive as well as to maintenance rations.

It has been fully demonstrated, however, that only under special conditions is the metabolizable energy, or fuel value, of a nutrient or feeding stuff the measure of its value to the organism. This was shown clearly by the early experiments of Zuntz and his associates, which antedate Rubner's results, while later investigations have fully confirmed the earlier ones, the difference being especially marked in the case of herbivorous animals. Zuntz & Hagemann† have demonstrated that this is the case with the horse.

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* Zeitschrift fur Biologie; 21, 250 and 337.

**U. S. Dept. of Agr., Office of Experiment Stations, Bul. 21; Conn. (Storrs) Experiment Station, 12th Report (1899), p. 71.

† Landw. Jahrb., 18, 1; 23, 125; 27, Erganzbd. III.

especially upon coarse feeds, Kellner* has shown the same thing to be true in the fattening of cattle, the authors† have demonstrated that it also holds in the case of maintenance and sub-maintenance rations of cattle, and Rubner‡ himself has shown that his earlier results were due to the comparatively low temperatures at which he experimented and constituted a special case of a general law. Opinions are still more or less divided as to the cause of the phenomenon, but there is no dispute as to the fact. Only a part of the metabolizable energy of the feed is ordinarily substituted for energy previously derived from the katabolism of protein and fat in the body or is recovered in the gain of flesh and fat made by the animal on abundant feeding.

Method of Determining Availability.

The relation between the amount of metabolizable energy supplied to the animal in its feed and the resulting effect upon the body may be determined by a comparison of two periods in which different amounts of the feeding stuff or ration in question are consumed. For example, in Periods III and IV of the experiments of 1905, two different amounts of the same timothy hay were fed. After making the necessary corrections as described in the detailed account of the experiments to be published later, it was found that the metabolizable energy of the rations consumed and the gain of energy by one of the animals (a loss being regarded as a negative gain) were as follows:

	Metabolizable Energy of Ration	Gain of Energy by Animal
Period IV	5981.4 Cals.	− 680.2 Cals.
Period III	3641.4 Cals.	−2096.1 Cals
Difference	2340.0 Cals.	1415.9 Cals

The excess of 2340 Cals. of metabolizable energy in Period IV as compared with Period III reduced the loss of potential energy from the body by only 1415.9 Cals. In other words, only 60.5 per cent. of the additional metabolizable energy supplied in Period IV was substituted for energy previously derived from the katabolism of body substance, while the remainder was disposed of by an increase of 924.1 Cals. in the heat production of the steer, corresponding to Rubner's "specific dynamic effect", the heat production rising from 5635.8 Cals. to 6559.9 Cals. It is customary in such a case to speak of the 1415.9 Cals. as the available energy of the hay added to the basal ration of Period III and to say that 60.5 per cent. of the metabolizable energy of the hay was available. Such a method of statement does not necessarily imply that the remaining 39.5 per cent. served no useful function in the body, but simply asserts that the net result to the organism was the same as if 60.5 per cent. of the metabolizable energy were substituted unit for unit for energy derived from the katabolism of body substance and as if the remaining 39.5 per cent. were useless. What the experiment really shows is that a unit of metabolizable energy in the hay had only 60.5 per cent. of the value of a unit of metabolizable energy in the body substance, (chiefly fat) previously katabolized. but the first method of expression is both common and convenient and may be retained.

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* Landw. Vers. Stat., 44, 257; 47, 275; 50, 245; 53, 1.

† U. S. Dept. Agric.. Bureau of Animal Industry, Bulletins 51, 74 and 101; Landw. Jahrb.,32, 665; 34, 861; 37, 423.

‡ Gesetz e des Energieverbrauchs bei der Ernährung, 1902.

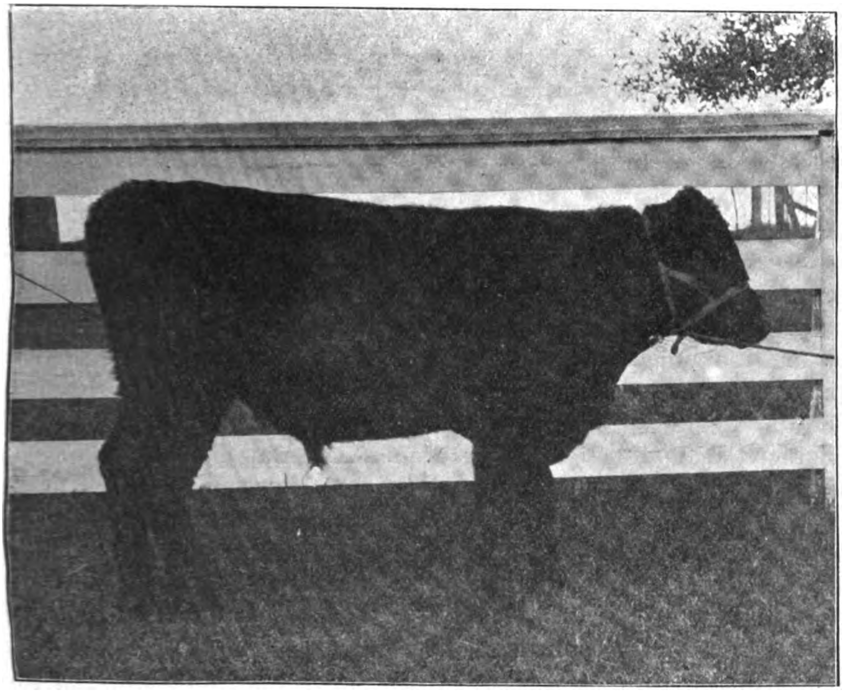
Experimental Results.

After correcting for differences in the amount of time spent standing and lying, for the slight variations in the live weight in the periods compared and for slight unavoidable differences in the proportion of hay or grain in the mixed rations, the average results are as shown in Table 4. Those for hay in the year 1906, as indicated, are of questionable value.

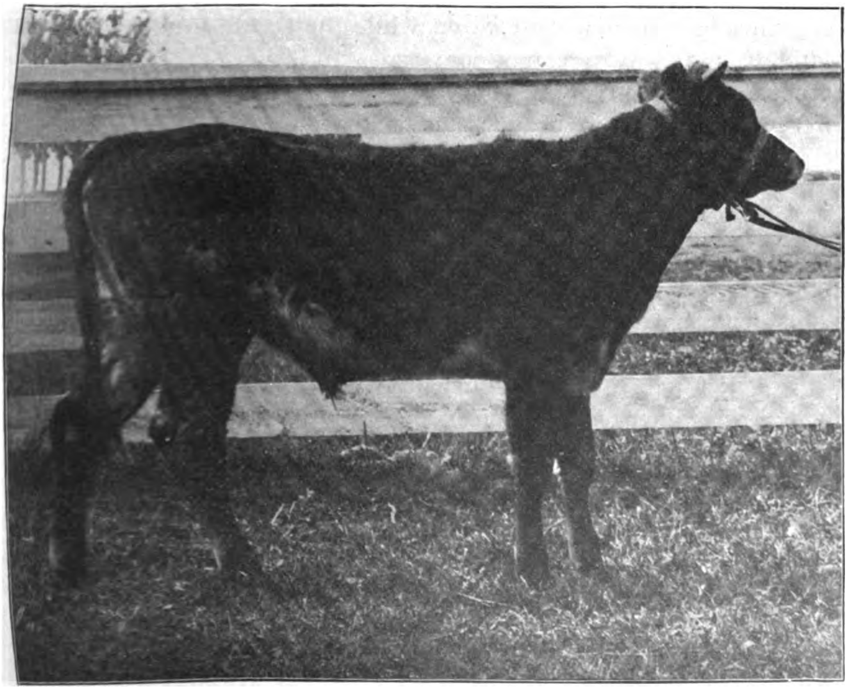
Table 4.—Summary of Availability of Metabolizable Energy.

	Pure-bred Steer %	Scrub Steer %
Timothy Hay		
Experiments of 1905	60.51	55.21
Experiments of 1906	71.49 ?	60.86 ?
Experiments of 1907	57.05	56.50
Wheat Bran		
Experiments of 1905	58.74	51.98
Mixed Grain		
Experiments of 1906	58.89	51.51
Experiments of 1907	61.55	57.71

Taking the results as a whole, they seem to indicate a small but distinct superiority of the pure-bred over the scrub steer as regards the availability of the metabolizable energy of the feed.



Pure-Bred Steer—Oct. 8, 1904.



Scrub Steer—Oct. 8, 1904.

This difference appears to be more marked in the earlier years, while as the animals matured the scrub nearly or quite overtook the pure-bred steer in this respect, so that it seems questionable whether the differences in the third year's experiments are of much significance.

In explanation of such a difference, little but speculations can be presented. It is not easy to conceive how any metabolic process or set of processes, such, for example, as are involved in the production of fat from carbohydrates, can be conducted more efficiently in one individual than in another. It would seem that if such a difference between individuals exists as is indicated by the foregoing results, we must seek for its explanation in differences in the character of the body substance gained or katabolized. Upon this point, of course, respiration calorimeter experiments afford but little information. They show the total gain or loss of ash, nitrogenous matter and fat (and glycogen), but reveal nothing as to the part of the body where they are deposited or katabolized, nor as to the exact nature of the material involved. It may not be without significance in this connection that, as shown on previous pages, the growth of the pure-bred steer was more largely in body girth, while the scrub steer increased relatively more rapidly in length and height, or that, as will appear later, the pure-bred steer showed a tendency to fatten while the scrub inclined to gain relatively more nitrogenous material. In other words, the difference in availablity may conceivably be related to the apparent difference in the nature of the gains or losses.

As regards any influence of age upon the percentage availabilty of the feed, the results appear indecisive. In the case of the hay, (aside from the questionable results of 1906), the differences are very small and in opposite directions with the two animals. In the case of the mixed grain of 1906 and 1907, there is apparently a tendency to a somewhat greater availability by the older animals. On the whole, the results as regards the influence of age afford little support to the belief in a greater ability of young animals to utilize the metabolizable energy of their feed.

Energy Required for Maintenance.

From the results of the two periods on hay alone in each year, it is easy to compute on the one hand the amount by which it would have been necessary to increase the supply of metabolizable energy to prevent any loss of potential energy from the body. or, on the other hand, to calculate the amount of potential energy which would have been lost by the animal had the ration been reduced to zero.

Thus in the case of the pure-bred steer in the experiments of 1907 for example, the metabolizable energy of the hay consumed daily in Period III was 6234.5 Calories and on this ration the body lost daily 1679.4 Calories, while a comparison with Period IV showed an availability of the metabolizable energy of 57.05 per cent. Evidently, then, to prevent the loss from the body of 1679.4 Calories it would have been necessary to add to the daily ration sufficient hay to supply.

$$1679.4 \div 0.5705 = 2943.7 \text{ Calories}$$

of metabolizable energy, making the total metabolizable energy of the daily ration

$$2943.7 + 6234.5 = 9178.2 \text{ Calories.}$$

If, on the other hand, the ration has been reduced to zero, the loss of energy per day by the animal would have been increased by

$$1634.5 \times 0.5705 = 3556.8 \text{ Calories.}$$

and the total loss would have been

$$1679.4 + 3556.8 = 5236.2 \text{ Calories.}$$

A ration, therefore, supplying 5236.2 Calories of available energy would have been a maintenance ration for this animal.

Computed in the manner shown in the foregoing example, the maintenance requirements of the two animals in the three

Table 5.—Computed Maintenance Requirements in Terms of Available Energy.

	Pure-bred Steer Cals.	Scrub Steer Cals.
Per day and head		
Experiments of 1905	4396	3946
Experiments of 1906	5228	4801
Experiments of 1907	5236	5821
Per day and 500 kgs. live weight		
Experiments of 1905	6649	7532
Experiments of 1906	6077	6806
Experiments of 1907	5186	6931

series of experiments were as shown in Table 5. For the sake of ready comparison, the results have also been recalculated to a uniform weight of 500 kilograms in proportion to the two-thirds power of the live weight.

The experiments of 1907, the results of which were the most satisfactory, show a marked difference between the two animals as regards the maintenance requirement, that of the scrub steer being 33.7 per cent. higher than that of the pure-bred steer. The results obtained in 1905 and 1906 have less weight, but nevertheless they show a difference in the same general direction. On the average of the three years' experiments the available energy required for maintenance per 500 kilograms live weight was:

Pure-bred steer	5971 Cals.
Scrub steer	7090 Cals.

Even omitting the relatively low result for the pure-bred steer in 1907, the average for this animal is materially lower than that for the scrub.

The correction of the results to a uniform time of 12 hours standing may be assumed to have approximately eliminated any difference in the maintenance requirement due to the influence of standing or lying. The scrub steer possessed the active, nervous temperament of the dairy type, while the pure-bred steer showed the quiet, almost phlegmatic disposition of the typical beef animal. The figures appear to show that this difference in temperament, aside from any effect which it had upon the amount of time spent standing or lying, very materially affected the maintenance requirement. If such differences prove to be characteristic of the two types of animals they will go far toward explaining the economic superiority of the beef type.

Gains in Live Weight.

During the months intervening between the respiration calorimeter experiments of each year, the animals received a ration sufficient to produce a normal growth but not to materially fatten them. The average gains per day and the amount of air dry matter in the feed consumed per kilogram of live weight are shown in the following table.

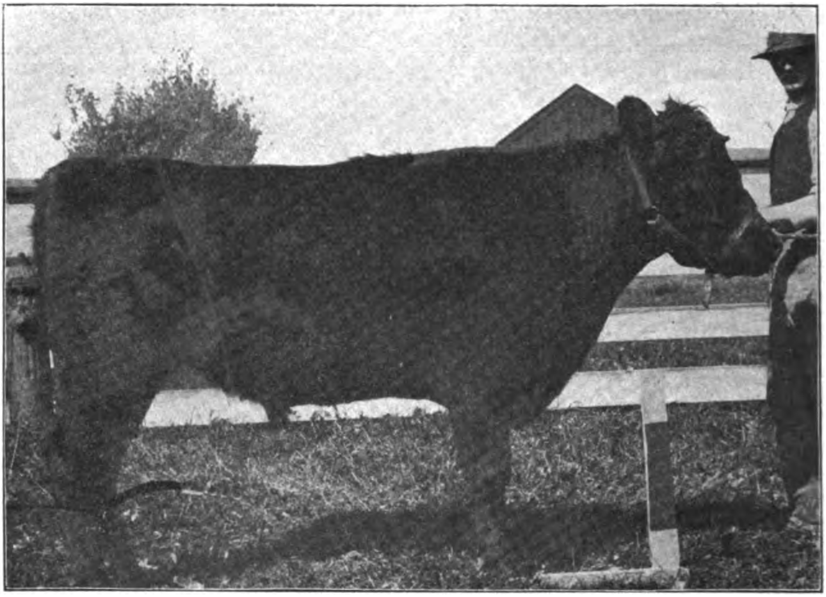
Table 6.—Gains in Live Weight in Intermediate Feeding Periods.

	Gain per Day Kgs.	Daily Gain Per 1000 Kgs. Mean Weight Kgs.	Air-dry Matter in Feed Eaten per Kg. Gain Kgs.
Pure-bred Steer			
Oct. 1-Dec. 11, 1904	0.482	1.828	11.00
Mar. 31-July 13, 1905	0.359	1.262	15.52
July 13-Sept. 28, 1905	0.594	1.762	8.15
Sept. 28-Nov. 28, 1905	0.448	1.199	13.62
Apr. 6-July 4, 1906	0.594	1.382	13.99
July 4-July 28, 1906	0.021	0.046	[204.30]
July 28-Oct. 27, 1906	0.112	0.243	39.73
Oct. 27-Dec. 4, 1906	0.726	1.509	9.66
Apr. 30-Oct. 28, 1907	0.367	0.654	
Oct. 28-Jan. 4, 1908	0.568	0.926	
Totals and Means			
Oct. 1, 1904-Dec. 4, 1906	0.426	1.149	13.68
Oct. 1, 1904-Jan. 4, 1908	0.414	0.942	
Scrub Steer			
Oct. 1-Dec. 11, 1904	0.620	3.213	7.63
May 5-July 13, 1905	0.559	2.608	9.60
July 13-Sept. 28, 1905	0.368	1.561	10.96
Sept. 28-Nov. 28, 1905	0.546	1.949	9.91
Apr. 13-July 4, 1906	0.429	1.318	16.01
July 4-July 28, 1906	−0.321	−0.946	
July 28-Oct. 27, 1906	0.305	0.873	14.69
Oct. 27-Dec. 4, 1906	0.410	1.105	15.46
Apr. 26-Oct. 28, 1907	0.241	0.593	
Oct. 28-Jan. 4, 1908	0.801	1.757	
Totals and Means			
Oct. 1, 1904-Dec. 4, 1906	0.422	1.875	13.37
Oct. 1, 1904-Jan. 4, 1908	0.412	1.260	

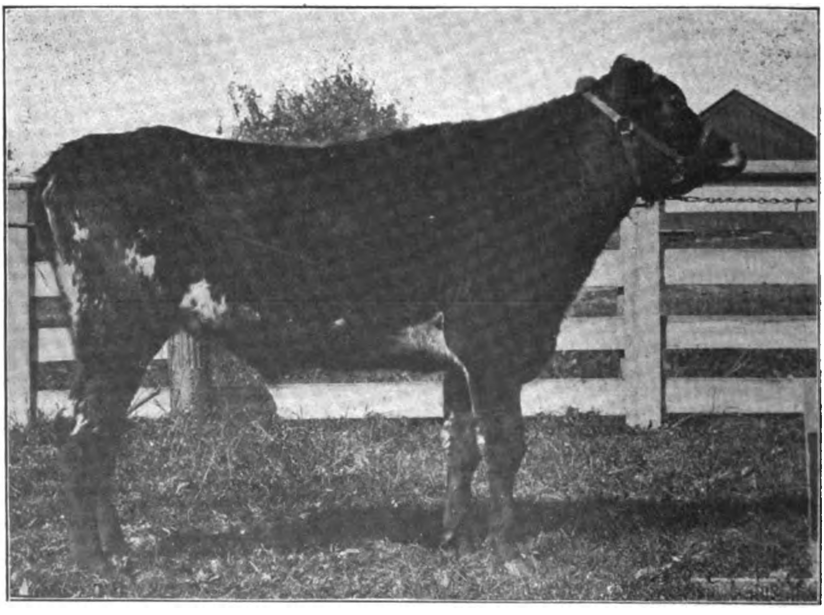
It appears from the foregoing results that the scrub steer produced a unit gain in live weight upon somewhat less total feed than did the pure-bred steer.

Character of Gain.

At intervals during the periods indicated above, the feces and urine of the animals were collected quantitatively so as to determine the digestibility of the total ration and the amount of protein gained by the animal. On the basis of these results, it is estimated that



Pure-Bred Steer—Oct. 15, 1906.



Scrub Steer—Oct. 15, 1906.

the average rations fed contained the amounts of digestible protein and of available energy shown in the following table:

Table 7.—Summary of Average Daily Rations Per Head.

	Pure-bred Steer		Scrub Steer	
	Digestible Protein Grms.	Available Energy Cals	Digestible Protein Grms.	Available Energy Cals.
Oct. 1-Dec. 10, 1904	374.4	6075	315.7	5294
Apr. 2-July 15, 1905	413.0	6570		
May 2-July 15, 1905			378.4	6682
Oct. 6-Dec. 3, 1905	405.6	7092	350.8	6327
Apr. 8-July 6, 1906	444.4	9542		
Apr. 15-July 6, 1906			399.1	7673
Oct. 26-Dec. 15, 1906	345.8	8264	315.8	7553

If we subtract from the available energy of the foregoing rations as thus computed the amount required for the maintenance of the animal, the remainder should correspond to the gain of energy by the animal. The results of this computation are contained in the following table:

Table 8.—Energy Content of Gain in Live Weight.

	Average Live Weight* Kgs.	Available Energy Per Day Cals.	Estimated Maintenance Requirement Cals.	Estimated Gain of Energy Cals.	Average Daily Gain in Weight Kgs.	Energy in 1 Kilogram Gain Cals.
Pure-bred Steer						
Oct. 1-Dec. 10, 1904	623.5	6075	3897	2178	0.482	4519
Apr. 2-July 15, 1905	293.7	6570	4207	2363	0.359	6583
Oct. 6-Dec. 3, 1905	373.7	7092	4918	2174	0.448	4853
Apr. 8-July 6, 1906	429.7	9542	5397	4145	0.594	6978
Oct 26-Dec. 15,1906	481.0	8264	5818	2446	0.726**	3369
Scrub Steer						
Oct. 1-Dec. 10, 1904	193.0	5294	3760	1534	0.620	2474
May 7-July 15, 1905	214.3	6682	4030	2652	0.559	4744
Oct. 6-Dec. 3, 1905	280.2	6327	4819	1508	0.546	2762
Apr. 15-July 6, 1906	325.5	7673	5326	2347	0.429	5471
Oct 26-Dec. 15,1906	371.2	7553	5813	1740	0.410**	4244

The data of Table 8 show that with the exception of the last period, in which the true gain of weight is somewhat uncertain, the pure-bred steer was notably superior to the scrub as regards the energy content of a unit of gain.

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* Average of initial and final weights for the period corresponding most nearly to the feeding period.

** Initial weight in this period is from a single weighing.

That a unit of gain by the pure-bred steer represented the storage of more energy than an equal gain by the scrub steer appears to be due largely to the greater proportion of protein with its large amount of accompanying water which seems to have characterized the gain made by the latter. Both the composition of the gain observed in the respiration calorimeter experiments and the results of the nitrogen balance trials show that the scrub steer had a notably greater tendency than the pure-bred steer to gain protein, while the pure-bred, on the other hand, was inclined to store up more fat. This result was confirmed also by chemical analyses of corresponding parts of the carcasses of the animals at the close of the experiments.

Pure-Bred Steer—Feb. 20, 1907.

Scrub Steer—Feb. 20, 1907.

Conclusions.

Our general conclusion from the foregoing data, then, is that the two steers did not materially differ as regards digestive power, percentage of feed energy metabolized or percentage availability of the feed energy. The pure-bred steer was superior to the scrub in that his maintenance requirement was less while his capacity to consume feed was greater. On the moderate rations fed, he manifested this superiority, however, not in the form of greater gain of live weight from a unit of feed, but in the production of higher quality of product, representing the storage of more energy available as human food.

Feed Requirements for Growth.

It is of interest to compare the rations consumed and the gains made by these two steers with the accepted feed requirements of such animals as formulated in the current tables of "feeding standards" for growing cattle. The most recent and generally accepted of these are Kellner's* which are expressed in terms of digestible protein and "starch values", one kilogram starch value being equivalent to 2356 Cals. of available energy. Kellner's standards are as follows, the starch values being reduced to their equivalents in available energy expressed in Therms.**

Table 9.—Kellner's Feeding Standards for Growing Cattle.

	Average Live Weight Per Head Kgs.	Requirements Per 1000 Kgs. Live Weight	
		Digestible Protein Kgs.	Available Energy Therms.
Dairy Breeds			
3— 6	140	2.80	34.63
6—12	240	2.30	29.45
12—18	320	1.80	24.74
18—24	400	1.30	21.68
Beef Breeds			
3— 6	150	3.50	41.00
6—12	250	2.80	33.93
12—18	350	2.20	26.39
18—24	430	1.50	23.56

The live weight of the pure-bred steer at the beginning of the investigation corresponded with the weight assumed by Kellner for animals of the same age, being, if anything, a trifle higher, but the weight of the scrub steer was considerably less. The later weights of the two steers cannot be compared with those predicated by Kellner for the corresponding ages on acount of the respiration calorimeter experiments, covering about three months each year, during which light rations were fed and little or no gain made. We may, however, compare our results with those expected to be obtained by the use of Kellner's standards by computing the average daily rate of gain in the intermediate feeding periods. From Kellner's figures, as given in Table 9, the expected gain per day and head may be computed as follows:

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* "Die Ernährung der Landwirtschaftl. Nutztiere", 4th Ed., 602.

** A Therm equals 1000 kilogram Calories.

	Dairy Breeds	Beef Breeds
Between 4½ and 9 months	0.392 Kgs.	0.392 Kgs.
Between 9 and 15 months	0.437 Kgs.	0.564 Kgs.
Between 15 and 21 months	0.437 Kgs.	0.437 Kgs.

The actual average daily gains by our steers for the periods covered by the rations of Table 7, as shown in Table 8, are repeated in Table 10 in conjunction with what may be called the virtual age of the animals, that is, the age exclusive of the respiration calorimeter experiments.

Table 10.—Average Daily Gains in Live Weight.

	Pure-bred Steer		Scrub Steer	
	Virtual Age Months	Average Daily Gain Kgs.	Virtual Age Months	Average Daily Gain Kgs.
Oct. 1-Dec. 10,1904	8.5-10.9	0.486	10.9-13.2	0.620
Apr. 2-July 15, 1905	10.9-14.4	0.359		
May 2-July 15, 1905			13.2-15.4	0.559
Oct. 6-Dec. 3, 1905	17.0-19.0	0.448	18.1-20.2	0.546
Apr. 8-July 6, 1906	19.0-22.0	0.594		
Apr. 15-July 6, 1906			20.2-23.1	0.429
Oct. 26-Dec. 15, 1906	25.0-26.2	0.726	26.2-27.5	0.410

On the average of the foregoing feeding periods, aggregating 17.7 months for the pure-bred steer and 16.6 months for the scrub, the average daily gains were, respectively, 0.426 Kg. and 0.422 Kg. The figures show clearly that the rate of gain during the feeding periods, outside of the respiration calorimeter experiments on limited rations, was fully as great as that predicated by Kellner for similar animals and would be very satisfactory in practice for animals not being fattened.

The rations shown in Table 7, computed to 1000 kilograms live weight in direct proportion to the latter, are as follows:

Table 11.—Average Rations Per 1000 Kilograms Live Weight.

Pure-bred Steer			Scrub Steer		
Virtual Age Months	Digestible Protein Kgs.	Available Energy Therms	Virtual Age Months	Digestible Protein Kgs.	Available Energy Therms.
8.5-10.9	1.42	23.05	10.9-13.2	1.64	27.43
10.9-14.4	1.40	22.22	13.2-15.6	1.77	31.18
17.0-19.0	1.09	18.98	18.1-20.2	1.25	22.58
19.0-22.0	1.03	22.20	20.2-23.1	1.23	23.57
25.0-26.2	0.72	17.18	26.2-27.5	0.85	20.35

Energy Requirements.

The rations of the scrub steer contained in the earlier periods of the experiments somewhat less available energy than the standards of the dairy breeds call for and a somewhat larger amount during the latter periods. The differences, however, are not very marked. The pure-bred steer consumed relatively less feed than the scrub and consequently the available energy of his rations is notably less in the earlier periods than that called for by the standards for beef breeds and somewhat less in the later periods. On these rations both steers made on the whole quite similar gains per head, which were entirely satisfactory from a practical standpoint. The scrub steer being the lighter animal, his gains were relatively greater, although, as has already been shown, this greater relative gain seems to have had a lower energy value per unit. The pure-bred steer, on the other hand, seems to have had a relatively low maintenance requirement and possibly the average beef animal would require more feed for this purpose than did this one. On the whole, the results upon these two animals indicate that for simple growth without material fattening, Kellner's standards as regards available energy might be somewhat reduced.

Protein Requirements.

As regards the protein requirements, we find a striking contrast between our rations and the accepted standards. Our two steers made entirely satisfactory gains on rations whose digestible protein ranged in the case of the scrub steer from 70 to 95 per cent. of the formulated requirements of the dairy breeds and in the case of the pure-bred steer from 50 to 70 per cent. of those of the beef breeds. The difference is greatest at the earliest ages and gradually diminishes. One of us* has previously called attention to the fact that the protein supply called for by the current feeding standards for growing cattle is greatly in excess of the sum of the maintenance requirement and the amount actually stored up in the body, and that we have no recorded determinations of the minimum protein demands of such animals. The quantities of digestible protein consumed by the two steers in this investigation, although less than those called for by the standards, were still considerably in excess of the amounts calculated in the publication referred to, but, on the other hand, our results afford no proof that the minimum was reached. Of course it must be regarded as probable that some waste of nitrogenous matter would be involved in the chemical reconstruction necessary in changing food protein to body protein, while it is not impossible that a certain surplus of protein may be necessary for, or at least favorable to, growth. The tendency of recent investigations, however, is to show that in all branches of feeding the minimum protein requirement has been considerably exaggerated. This has been shown to be true of the maintenance requirement and of the requirement for milk production, while our results suggest that it is also true for growth. At any rate this branch of the subject seems worthy of further investigation.

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* Armsby: U. S. Dept. of Agr., Bureau of Animal Industry, Bul. 108, pp. 27-29 and 57-65.

Sci 1138.5.4

The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 106

A MAIDEN BLUSH ORCHARD WELL TILLED

THE APPLE IN PENNSYLVANIA:

VARIETIES, PLANTING AND GENERAL CARE

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
DECEMBER, 1910

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 106

THE APPLE IN PENNSYLVANIA:

VARIETIES, PLANTING AND GENERAL CARE[1]

JOHN P. STEWART

The kind of fruit most widely adapted to Pennsylvania is the apple. This state as indicated by the census of 1900 is practically in the center of the leading apple-producing district of America. The best markets are readily accessible, the fruit now being grown by our leading orchardists is unexcelled, and suitable conditions are abundant. The opportunities are being realized in some sections of the state, but in others they are scarcely touched.

The success of an orchard depends upon location, varieties, and care. A proper location is one that has suitable soil and climate for the kind of fruit to be grown, *sufficient local elevation* to give good drainage of air and water, and convenient access to market if the orchard is to be commercial. The soil should be reasonably porous and moisture-retentive; sufficiently deep and level to permit tillage at least occasionally; and the elevation not so great as to unduly expose the trees to winds and drought.

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[1] During the past three years Professor J. P. Stewart has been making an investigation of the causes affecting yield and quality in apples. Experiments are being conducted in orchards located in the counties of Adams, Bedford, Bradford, Center, Chester, Franklin, Lawrence, Mercer and Wyoming. They contain 49 acres of bearing trees and 42 acres of trees not yet in bearing, the total number of trees under investigation aggregating over 3,600. A report of progress will be found in Bulletin 100 of this Station. The conduct of this investigation has offered Professor Stewart exceptional opportunity for observation as to methods of culture and adaptation of apples and other fruits. A brief resume of these observations will be found in this bulletin.
THOMAS F. HUNT, Director.

The selection of varieties requires great care, and special attention to it is given later. In general, however, a variety should not be selected merely because it does well somewhere else. Neither does it follow that the best of the local sorts are necessarily the best to grow. With any kind of fruit, the ideal is to grow only those varieties that reach greatest perfection in the soil and locality concerned. Hence, the best of the local fruits should be known, and also some consideration be given to the best varieties under similar conditions elsewhere. The final selection, therefore, depends upon a study of reliable lists and opinions, *checked by local experience and trial.* A common mistake is to have too many varieties. Eight or ten, ranging through the season, are ample even for large commercial plantings and usually this number may well be reduced.

Securing Early Returns.

An important barrier to the beginner in apple-production is the delay in returns until fruiting. It may be met by inter-crops or fillers, or by a combination of both. With the combination, the orchard is carried for about the first three or four years by the inter-crops, after which the fillers may be expected to give returns. In general the best plants for the inter-crop are early annuals that require tillage in the fore part of the season and do not require too late a stirring of the soil in their harvesting. From the standpoint of the trees, the least harmful are tilled, leguminous inter-crops, such as peas or beans, because of their favorable nitrogen and moisture relation, but cabbage, cantaloupes, potatoes, or other hoed vegetables if accompanied by proper fertilization are often entirely satisfactory. All cereal inter-crops are to be avoided, with the apparent exception of corn, for the first year. Its least harmful form is probably early sweet corn. Near the trees, however, clean tillage should be maintained.

For fillers, peaches are undoubtedly the *most profitable,* if the soil and location are satisfactory for both them and the apples. Such conditions are somewhat rare, however, and since peaches are rather hard on the land and favor the development of the curculio, besides greatly complicating the orchard operations in general, it is usually considered better to use early bearing varieties of apples. The fillers may be planted in the rows of one direction only, leaving the inter-spaces for vegetables or other tilled crops used in the combination indicated above. This plan is usually most satisfactory, if sufficient labor and markets are available Both fillers and inter-crops must be removed promptly, when the space is needed by the permanent trees, and the chief argument against their use is the failure to do this.

Cultural Methods and Fertilization.

The best cultural method for most situations is tillage with a leguminous cover crop while the trees are young. If the inter-crops chosen interfere with the planting of the ordinary leguminous cover crops, rye, or rye and vetch, may be used as late as the close of September. The plowing under of the cover crops should be completed usually not later than the middle of July, when normally the leguminous cover, such as hairy vetch or crimson, mammoth or medium red clovers, should be sown.[1] Where washing is bad, it may largely be prevented by tilling alternate interspaces every other year thus giving each tree annual cultivation over half its roots. Three or four inches is deep enough for tillage over tree roots, and a double action disc or cutaway harrow is often very satisfactory.

Where such tillage is inadvisable, good results may be obtained with the mulch system if accompanied by proper fertilizing A leguminous cover is preferable as a basis for the mulch. The mulch should be deep enough to keep down most of the growth immediately over the tree roots, which may require some additional materials such as straw, leaves, swamp hay or dead weeds. Such a mulch treatment has shown distinct value in our experiments in hastening bearing when the trees have reached proper size. After the bearing habit is established a return to tillage at least every second or third year should be made when possible, increasing the frequency of tillage with the age of the orchard and the demands of the fruit.

Permanent *grass* covers, however, are usually very objectionable over tree roots, probably on account of the greater demand of grasses upon nitrogen and moisture. The soil should be plowed and returned to the leguminous cover, for which white clover and alsike are probably as permanent as any, whenever grasses regain possession.

The need and value of soil fertilization is largely a local problem. In general, young trees are less likely to be benefited by it than old, and it is usually bad practice to put any kind of fertilizer in the holes at planting time. In case of any considerable additions of plant food, it is best to try the contemplated application on a few trees before extending it to the whole orchard. Stable manure at the rate of about ten tons per acre is one of the best treatments that can be given to an orchard, either on sod or in connection with tillage. But a commercial fertilizer carrying about 30 pounds of actual nitrogen, 60 pounds of actual P_2O_5, and 50 pounds of K_2O, has proved almost as good in our experiments.[1] If sufficient nitrogen can be obtained with manure and cover crops, however, there is of course no need of further addition.

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[1] This covercrop system is somewhat elastic, the exact dates for the chief operations varying primarily with the abundance of moisture. For example, if there is plenty of moisture for both crop and trees, the plowing may be deferred somewhat and the seeding made earlier than the dates indicated, with reverse modifications if moisture is lacking. The plowing should not be done too late, however, on account of increased injury to the season's absorbent tree-roots, nor should the seeding be done so early as to unduly hasten the maturity of the trees or reduce the final size of the fruit through competition for moisture.

Purchase and Planting of Trees.

In buying trees one should specify only first grade trees, true to name, free from injurious insects and disease, and not over two years from the bud or graft. The trees should reach the buyer in strong living condition, not shriveled nor giving evidence of improper storage or stunted growth. Trees with the limbs well separated in point of origin are also much preferable to those in which they all come out at about the same height, as will appear later. The particular form of propagation, whether whole or piece root[2], is immaterial so far as growth in the orchard is concerned; and caliper is a better basis for grading than height.

It is best to deal direct with responsible nurseries and to order early, submitting requirements to a number of firms for bids. The trees may be held at the nursery subject to order at planting time. Where the winters are not too severe, fall planting is advisable, otherwise plant in the spring as soon as the ground is fit, though it may be done later if the trees are kept satisfactorily dormant. The trees should be examined and "heeled in" at once on receipt, pressing the dirt firmly about the roots. The roots should be shortened back to about six or eight inches, and those broken or bruised should be removed with a smooth cut above the place of injury. This pruning is often done before heeling in.

The planting system most commonly followed is that of *squares or oblongs*. This is varied into the quincunx by planting a tree in the center of each square. The latter plan is of value when in doubt as to which of the two varieties should be used as permanents, and also when fillers are used. Of late, many people are favoring the triangular or hexagonal plan. This plan enables one to cultivate, spray, and plant fillers in more directions than those above; and better utilizes the space in the orchard. In other words, with a given number of trees per acre, more space and light are available to each if planted on the hexagonal plan.

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[1] For further information and data on fertilization and cultural methods, see our Bulletin 100, obtainable on application to the Director of the Experiment Station, State College, Pa.

[2] Data on this may be found in our Annual Report for 1907-8: 193-200; and also in Kansas Bulletins 65 and 106; Illinois Bulletin 21; and Alabama Bulletin 98.

Success in planting is largely a matter of avoiding all unnecessary root-exposure and thorough firming of the soil about the trees. Soaking the roots in water for some hours before planting is one of the best means of securing sure growth. "Puddling" them is also often desirable if they are to be long exposed. If the trees are watered it should be done thoroughly, adding the water before the holes are completely filled. Set trees from one to three inches deeper than they were in the nursery, placing the sides with heaviest roots toward the prevailing winds, and leaning the tops slightly toward the southwest.[1]

The distance of planting varies from 30 to 40 feet, depending on the size and habit of the variety. The proper distance may be decided by observing the space required by full grown trees of the variety in the soil and locality concerned. It is well to remember, however, that the roots usually extend much farther than the branches and it is always better to plant a little too far apart than too close. Outside rows are proverbially best. In western New York, mature orchards of Baldwin and Greening regularly show the greatest profits from trees planted about 40x40. When fillers are used, a distance of 36 to 40 feet is undoubtedly preferable for the permanents of most varieties, though there are some exceptions.

To insure productiveness, in the case of some varieties it seems necessary to make some provision for cross pollination. This may be accomplished by planting not more than four rows of the same variety in a block and alternating them with other varieties that bloom at the same time.

Forming the Heads and Pruning.

The formation of the tree head by pruning to the form and height desired is usually done after the trees are set. People differ as to the exact type of head that is best. The writer prefers the low open type, except for the more spreading growers such as Rhode Island Greening, Smokehouse and Jonathan. Such varieties should be headed higher and they also *may* be trained to a central leader. The mistake of starting the heads with too many limbs is very common. For most trees, three limbs properly distributed vertically and laterally are sufficient. This number avoids heavy pruning later. If good distribution and balance cannot be secured with three, however, either four limbs may be chosen or the tree cut back to a whip for a new output.[1] Small defects may be remedied and growth directed by heading the limbs slightly above buds pointing in the desired directions.

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[1] In planting, much labor may be saved and the work efficiently done by the proper use of a plow. With it deep dead-furrows are turned out for the rows and again plowed shut after planting. The exact position of the trees can be secured by cross furrows or by the use of a wire long enough to reach the full length of the rows, with the planting distances firmly indicated on it. For further discussion and details of planting, see Storrs Connecticut Bulletin 62:112-126.

The heads, however, should not be too low. A good height for the lowest limb on apples is about 30 to 36 inches, with the others preferably six inches or more apart. It should be remembered that the trunk does not lengthen, except by pruning off lower limbs, so that the height chosen at the start is the permanent one The vertical space recommended between the limbs of the head is very desirable to avoid the development of weak forks, with consequent danger of splitting apart under pressure. Poor and good formation of tree heads are shown in Figures 1 and 2.

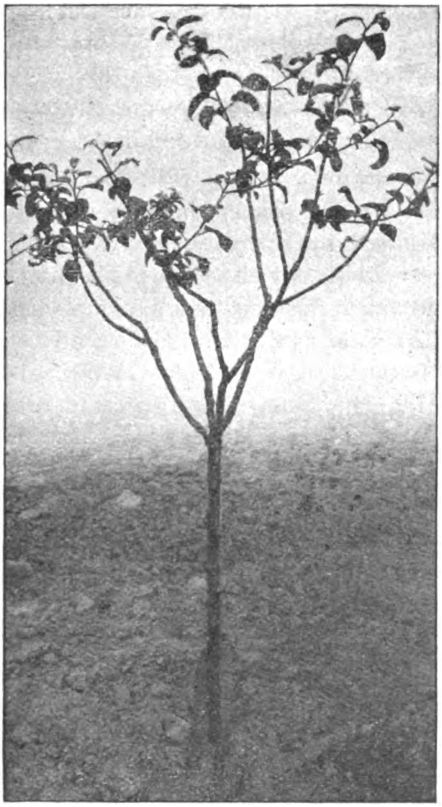

Figure 1. Tree well balanced, but limbs come out too close together; likely to develop weak forks.

Later Pruning.—In the later pruning and training, we have much yet to learn. For example, we have long been under the impression that winter pruning increases both vigor and growth, while summer pruning decreases them but favors fruitfulness. This may be true. But according to the Woburn experiments,[2] all pruning regardless of seasons tends to delay fruiting and reduces both yield and growth, the reduction being approximately in proportion to the severity of the pruning. There is much good physiological as well as practical support for the latter view also. Hence, at present it appears that the best practice is to reduce all pruning to a minimum, though it cannot properly be omitted entirely. Early bearing and maximum yields are obviously not the only objects to be sought. Proper growth, manageable tree form, light, opportunity for the individual fruits to attain their proper color and development, facility in spraying and harvesting—all these are quite as important and their attainment requires some cutting.

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[1] Trees that start slowly also are often improved by cutting back rather severely.

[2] These are undoubtedly the most careful experiments on pruning yet reported. See Report for 1907 of the Woburn Experimental Fruit Farm, England.

In all pruning or training, therefore, it seems that the *correct principle* is to do the least cutting possible to obtain or preserve manageable form and get light to the fruit. In the writer's opinion, this is best accomplished during the early development of the orchard especially, by "pinching" and training in early summer, thus removing the superfluous limbs before they have been formed and permitting the main growth to be made in the limbs that are saved. These limbs apparently make a greater growth than they otherwise would and from our present experience it seems that a net gain in size is shown over trees pruned as usual during the dormant season.

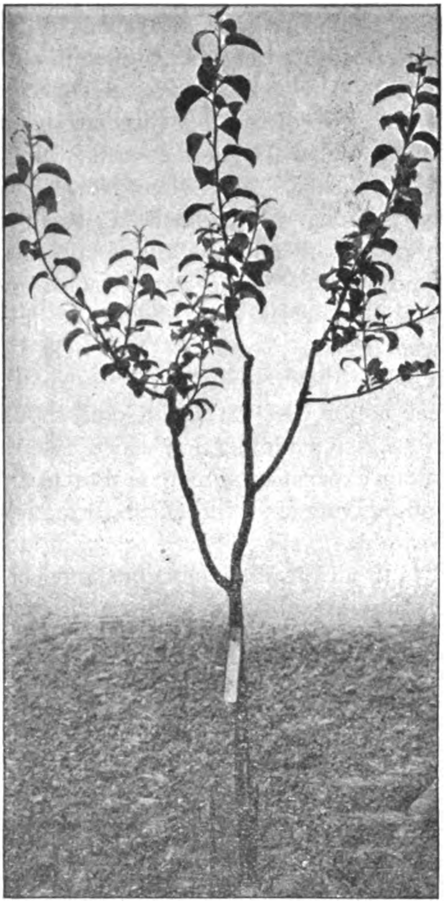

Figure 2. Main limbs well separated. Present slight lack of balance can be remedied by later training.

With this general view of the subject and the trees properly headed, the orchardist may follow whatever system of later training he prefers. A plan that we are using is described below and is partially illustrated in Figures 1 and 2. As a definite plan it has some advantages, though of course it need not be followed rigidly. Some adjustment to the individual peculiarities of the trees is often required. It may be called the "dichotomous system" on a tripod base.[1] In it, each of the three (or more) limbs originally chosen is headed back somewhat and restricted to the development of two, the two being separated in point of origin, and so chosen in direction of growth as to more evenly balance and open the top. On each of these limbs, in turn, two or possibly three are permitted to develop, being chosen as before, and the process continued until the main framework of the tree is established. This should be largely accomplished within three or four seasons. In the later stages of this development the pruning should gradually be reduced and finally should consist wholly in the removal of interfering or otherwise undesirable branches. In the later pruning special care should be taken to save fruit spurs and to keep bearing wood low and well distributed through the trees, thus avoiding the familiar "leggy" or "cowtail" effects. Contrary to a prevalent notion, the early blossoms should be left on, unless they appear in excessive numbers, in which case they should be thinned. As shown in our experiments, there is no real antagonism between normal growth and bearing and the early formation of the bearing habit is highly desirable.

In all pruning the cuts should be made close to the parent branch, leaving no stubs, and any wounds of an inch or more in diameter should be covered with thick lead paint of grafting wax. The quickest healing of large wounds is probably obtained by pruning just about the time that growth starts, though it should be timed so as to avoid excessive "bleeding:"[2] Keep water sprouts off main limbs to avoid blight cankers.

Protection of Trees.

During the early years some protection must be given against mice, rabbits and borers. Screens for the former and mounding-and-cutting-out for the latter are the methods commonly employed, but a protective covering, such as thick, pure, oil-lead paint, without any turpentine or "dryer" in it, has certain advantages and has been satisfactorily used. Any covering is probably best applied about the middle or latter part of June, in order to be in best condition during the laying period of the borer. Partially girdled trees, if discovered in time, can usually be saved by preventing the drying out of the tissues. This may be done by a covering of grafting wax, lead paint, or sometimes by mounding deeply enough to keep moist.

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[1] Dichotomous(di kotomus) means "regularly dividing by pairs from below upwards," or in a word "two-forked." This same plan in general is being used by M. B. Waite of Washington, D. C., and possibly by others, though it apparently has not been described.

[2] For further discussion and details of pruning, see U. S. Dept. of Agr. Farmers' Bulletin No. 181, and Paddock and Whipple Fruit-growing in Arid Regions, pages 80-146.

Spraying.[1]

Proper spraying is one of the fundamentals in the profitable production of apples. No amount of attention to other things can make up for its absence or defects, though the demands upon it may be greatly lessened by good care in other respects. Thus apple scab, which passes the winter in the fallen leaves, may often be practically eliminated during the following season by their destruction or removal. But as with other sharp tools, the use of sprays requires some care. Either waste of money or actual injury may follow their careless use. The period of greatest danger of injury from bordeaux seems to be while the young fruit is still covered with minute hairs and before its stomates have been changed to lenticils,[2] a change which is completed within about six weeks after petal fall. It is least satisfactory, therefore, in the second and third sprays indicated below but may be used in any of the others.

For the second and third sprays, lime-sulphur at a density of about 1.007 to 1.01 now seems best,[3] and it is also used for the other sprays. For the second spray and especially if only one application is to be given, it is probably best to use the greater strength, 1.01. This spray, in combination with a proper arsenical,[4] is not only excellent for scab, apple worms and curculio, but it is also very useful against the young of our common scale insects. In fact, during the past summer we were able to clear a tree entirely of San José scale with three sprays, the first being applied immediately after the young began to emerge and the others following at intervals of about ten days.[3]

Some injury to the foliage, and occasionally to the fruit, may result from lime-sulphur as well as from bordeaux. This injury is especially marked when the epidermis of the leaves or fruit has already been broken by fungi, insects, frosts or spray materials. It now seems probable that lime-sulphur injury is more severe upon

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[1] See our general spray bulletin for spraying details; also Bulletin 99 for the preparation and use of lime-sulphur; and Bulletin 86 for similar facts concerning miscible oils.

[2] See New York Geneva Bulletin 287.

[3] See our Bulletin 99 for diluting lime-sulphur, and our Annual Report for 1909-10, for detailed results in the summer control of scale.

[4] High grade and relatively insoluble lead arsenate now seems safest for this combination. It is added at the rate of 2 pounds of the paste, or 1 lb. of the powder, to 50 gallons of spray.

broken epidermises than bordeaux, though less harmful on sound ones. It is therefore especially liable to do injury when used after scab attacks are well under way or after breaks have developed from previous applications of bordeaux or lime-sulphur.[1] This emphasizes the necessity of keeping the foliage and fruit well protected from insects and disease, and also suggests that too many applications, or certain successions of sprays, are very inadvisable.

Spraying Plan[2] for Apples in Foliage.—To insure effectiveness and avoid waste, it is important that the exact times and purposes of the various sprays be clearly understood. The times of application and chief enemies are as follows:

(1) When the blossoms are just showing pink or slightly before. For apple and pear scab, canker worm and bud moth.

(2) May begin when petals are two-thirds off and should be completed within ten days thereafter. The most important spray. For scab, codling moth or apple worm, and curculio. Fill calyx cups.

(3) About two weeks later. For codling moth, curculio, apple blotch and late infections of scab.

(4, 5 and 6) If the orchard is liable to attack by bitter rot or apple blotch, spray three times with bordeaux (3-3-50) at intervals of about three weeks, beginning 8 or 9 weeks after petal fall.

(Other Sprays): To be made where needed if not sufficiently provided for by those above.

(a) For fungous fruit spot of Jonathan, etc., lime-sulphur, as above about July 1.

(b) For second brood of codling moth or for the foliage-eating caterpillars of late summer; lead arsenate at the rate of two or three pounds to fifty gallons of water, about August 1.

Of these sprays, the first tends to increase the size of the crop by preventing loss of blossoms and young fruit through attacks of scab on their stalks. It is especially necessary when the weather preceding blossoming is damp and cool. The second spray is the most important for both scab and codling moth, so far as the fruit remaining on the tree is concerned. It also doubtless prevents much additional loss of fruit from attacks of the plum curculio, which recent observations indicate to have much to do with part of the so-called "June drop." The third is mainly a "retoucher", though it gives a good coating of poison on the foliage when the apple worms are hatching in maximum numbers, and with us has proved valuable against curculio.

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[1] The exact influences that govern this lime-sulphur penetration or breaking of the epidermis are apparently complex and but partially understood. It occurs most readily through the under-surface of the leaf, but is not confined to it. The breaks may not be of special importance in the spray actually producing them, because they are most likely to be effected near the close of the evaporation period (See our Annual Report for 1908-09, pp. 288-89), and just before the relatively insoluble and harmless lime-sulphur products are formed. But they are of great importance in giving the opportunity for severe injury by the later sprays. At present it seems that the chief factors concerned in the penetration are: purity of the spray material; density and abundance of the application; size of the drops that collect, and the time required for their evaporation (suggesting the advisability of moderation in the amount of application and avoidance of "muggy" days); the differing resistance of varieties; and finally an apparent decided seasonal difference in varietal resistance. On the last-named factor, for example, our tests on apple foliage during the past season showed more burning from 1.01 solutions than we obtained during 1909 from solutions of 1.02, or twice as dense.

[2] This plan involves the use of a combined insecticide and fungicide. If any of the enemies named are unlikely to be present, the corresponding spray or the insecticidal or fungicidal part may of course be omitted. In other words, spray for definite things, applying neither too much nor too many sprays.

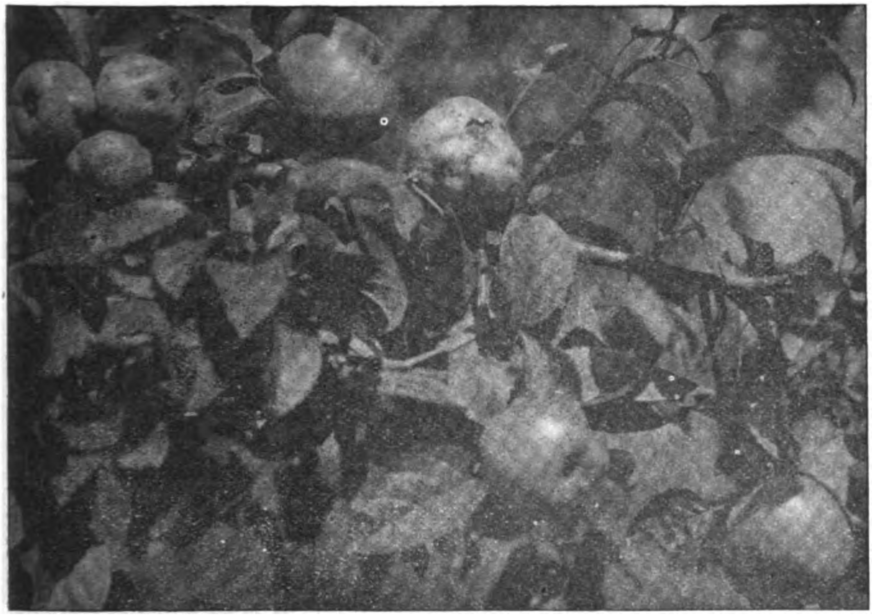

Figure 3. Apples unsprayed, showing effects of curculio. These marks are caused by feeding or egg-laying punctures that failed to develop larvae. When the eggs hatch the fruit drops. We have prevented these injuries almost entirely with lead arsenate and lime-sulphur.

Thinning.

When the crop on a tree is too large for normal maturity, thinning is of value and should always be given. Under such conditions it increases the size of the fruits; avoids breakage of the tree; reduces drain on both tree and soil by avoiding unnecessary seed production; and probably increases quality by affording opportunity for normal development. It also doubtless tends to increase the crop of succeeding years, though this has not yet been actually proved experimentally. When needed, thinning should be done as soon as possible after the June drop is largely over. In some localities, later thinnings are also made as the demand arises, giving special attention to the removal of defective fruits, so that the crop at picking time is practically all first grade.

Picking and Proper Handling of Fruit for Storage.

The proper time for picking apples is also very important. Too early picking sacrifices color and quality and also fruit spurs,[1] while picking too late results in loss of keeping qualities and often in loss from winds. The best time of picking for most apples, therefore, is when they are "hard ripe", i. e., when they have developed their full size and redness, but have not begun to soften nor to show the yellow colors, except perhaps in occasional specimens. Apples that develop no red color are picked when they have reached full size, or when occasional specimens have begun to soften, or to part readily from the twig. Summer and early autumn varieties, intended for immediate use, are best ripened on the trees, otherwise they should be picked as above. In many cases, two or more pickings are found desirable and profitable, to permit undeveloped fruits to mature. Climbing through the trees in picking should be avoided, step ladders and light cedar ladders of suitable length being used instead.

Along with picking at the right time, the best keeping qualities are secured by avoiding bruises and broken skins and by immediate cooling of the fruit. Leaving the apples in piles with the sun beating on them is exceedingly damaging to keeping quality. The breaks and bruises are probably best avoided by picking into round bottomed, cloth-lined, swing-handled baskets. In storage, temperatures of about 30° to 35° F. are satisfactory. A good storage house, or rented space in one, relieves one of the necessity of selling at once and thus often secures distinctly better prices, even at picking time. The best kind for the commercial orchardist to own is probably one using the gravity brine system.

The Packing of Apples.

Even after first grade fruit is grown the profits may be lost by careless or improper packing. In general, the essentials of a good pack are: clean, odorless packages; fruit strictly true to grade throughout; reasonable uniformity in size and color; and sufficient compression to avoid looseness in transit. The labeling and varietal name should be correct, and the name and address of the grower or the person in whose interest the packing is done should be given.

The particular style of package varies with the conditions to be met. Early apples are usually best marketed in peach baskets, unless the distances are too great. For the later varieties, barrels or boxes are preferable. The relative value of the latter packages depends largely upon the amount of fruit to be marketed, and upon its uniformity, perfection and quality. For the general wholesale marketing of the East, the barrel is undoubtedly best, and the greatest total gains are doubtless obtainable by thoroughly improving the style of packing in it.

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[1] Fruit spurs are often shamefully broken or pulled off with the apples by careless workers. A little attention to secure a proper tilt or bend at the junction of the stem and spur will avoid this. A straight pull is to be avoided.

For strictly high grade and high quality fruit, however, the best returns are to be secured by proper packing in boxes. Proper packing is different from merely setting the fruit in. Neither does it include the "jumble" pack nor slack boxes. Such work is likely to diminish rather than increase the returns. The use of cushions or layer papers to fill the space is also objectionable. A really well packed box is one that has about an inch of "crown" in the center, rounding off smoothly to about one-fourth inch at the ends, and the layers fitted so well that the box without cover may be stood on an end and the apples remain in place. This standard of course need not always be secured, but it will serve as a test of one's work. The diagonal pack is much preferred to the straight or off-set packs, and the successive layers should be alternated so as not to bring the apples directly above one another. Neat wrapping of the apples with paper of ordinary newspaper grade, is desirable, and a paper lining for the boxes may be used.

The best material for boxes is planed white spruce, with solid pieces for the ends[1] and sides, of ¾-inch and ⅜-inch thickness respectively. The top and bottom may be either solid or in two pieces, to permit somewhat greater spring, and the thickness commonly used is one-fourth inch. Cleats of the latter thickness are used in nailing. The size of the apple box unfortunately is not yet uniform. The size that has been recommended for national legislation is one containing 2342 cu. in., or about the capacity of the present Colorado box. The legal box in Canada, and the "special" of the far West, is 10x11x20, while the "standard" box of the latter section is 10½x11½x18 inches, —all inside measurements.[2]

Soils.

Apples thrive on a fairly wide range of soils, the limits varying from rather light sandy loams to heavy clay loams, or even clays. Most varieties, however, do best on medium loams of at least moderate depth and fertility and of proper moisture capacity. A good general test of the fitness of a soil and locality may be found in the springing up and thriving of apple trees in fence rows or other waste places.

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[1] Paneled ends or those with a groove are preferred by some on account of their greater ease in handling.

[2] For details of packing see files of **Better Fruit**; Oregon Bulletin 94; Bulletin 19, Dairy and Cold Storage Commission Series, Ottawa, Canada; and Paddock & Whipple, Fruit-Growing in Arid Regions.

Some varieties undoubtedly have rather decided preferences in soils, but the subject has received relatively little attention as yet and positive statements are not here attempted. The designations of preference given in the list below, however, are believed to represent the best opinion on this matter at present available. They should at least raise the question of varietal adaptations in the minds of prospective planters and afford a basis for clearer discrimination in the local study of varieties. Erroneous opinions of the local value of a variety are often formed by failing to consider the soil factor. The designations given are based largely upon the work and reports[1] of H. J. Wilder, of the Bureau of Soils. The additions and minor deviations from his reports are made on the writer's own responsibility. It is recommended, however, that so far as possible the local behavior and preferences of commercial varieties be carefully studied before assuming any large risk in planting.

VARIETIES.

The relative commercial importance of varieties is indicated by stars in the list below. Those marked with two stars (**) are considered to be fully commercial; those with one star (*) limited commercial; and those marked with a dagger (†) are good as fillers. The others may be limited commercial in some localities or are good for home orchards. The accessibility and character of the market should of course be given consideration, especially in the case of summer varieties. The letters following certain varietal names indicate soil preferences as follows: H (heavy) for clay loams; M (medium) for intermediate soils or loams; L (light) for light soils or sandy loams. Varieties separated by colons (:) are of practically the same season; otherwise they are named approximately in order of ripening. In the preparation of this list we have been aided by helpful criticisms of numerous growers and horticulturists. We have been unable to follow the ideas of all, yet we believe the list as it stands to be safe and conservative. We realize, however, that it is hardly possible for it to be entirely free from error and hence will welcome any further suggestions tending toward its improvement.

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1. See American Pomological Society Report for 1909: 138-148.

A. Varieties for Southern Pennsylvania, and Lower Altitudes in Central Pennsylvania.

Summer Varieties.

Yellow Transparent*†.—Early July. Hardy early bearer and productive; scab resistant[1]; erect grower and vigorous, though not large; quality medium; ripens fairly evenly; very tender textured when fully matured; and tree is quite subject to blight. Has done well on medium to heavy soils and is also reported good on light soils. A Russian variety:[2]

Early Harvest.—Subject to scab, slightly later and less prolific than Transparent; usually irregular in size, but good for home use because of high quality:

Earlyripe*—Vigorous grower and blight resistant; ripens very quickly; reported early and satisfactory in bearing; very good cooker and good for dessert; one of the best shippers and general purpose apples of its season. Size good but color only fair, being yellowish-green, and hence needs to be known before fully successful on the market. Often difficult to get true to name from the nurseries. Has been confused with Lowell, a later and poorer variety, by some nurseries.

Red Astrachan.—Another Russian variety, widely grown and recommended. Fairly productive, but often tardy in bearing. Fruit is usually irregular in size, an uneven ripener, and often over-stocked on the market, where it quickly loses its prime:[2]

Benoni.—Excellent for dessert; very mild sub-acid, good color, red, satisfactory bearer but usually a trifle small for the general market:

Primate.—One of the best of its season for the home orchard owing to fine quality, good size, long period of ripening, and reliable productiveness. Somewhat susceptible to canker and too tender for ordinary commercial use.

Starr*.—Early and prolific; fruit usually very large; good for dessert and very good for cooking; good shipper and considered fully commercial in central New Jersey. Said to do well on light soils:

Oldenburg (*Duchess*)**†—More widely reported as valuable commercially than any other variety of its season, though it has not been so productive in some localities. Very early bearer and regularly productive; fruit of good size and appearance; used for cooking; too sour for dessert:

Williams (*Red*)*.—Regarded in Delaware as one of the best of the summer apples. Good for both dessert and cooking; firm textured and a good carrier. The tree requires careful pruning when young as it is a rather scraggy grower. Not sufficiently tried in southern Pennsylvania as yet but its behavior elsewhere warrants extended trial; Probably fully commercial in parts of this state under right conditions and care.

Early Autumn Varieties.

Summer Rambo*.—Highly prized in southern and southeastern counties. Tree vigorous and hardy, early and annual bearer, rather erect habit. Ripens over long season. Fruit large, high quality; good keeper for its season; rather tender textured for ordinary handling and said to be sometimes subject to dropping.

Gravenstein.—Unexcelled for cooking by any variety of its season and very good for dessert. Usually bears fairly early; productiveness variable in southern part of state but reported very good in notheastern part. Tree large and vigorous. Fruit is large, but is apt to be irregular and is subject to loss by dropping; likely to do better in other regions:[2]

Maiden Blush.**—M to H. Satisfactory for home or market. Tree hardy and vigorous, of spreading or occasionally ascending habit. On many soils it eventually needs 40x40 feet space. Often needs thinning to secure uniformity, and usually must be carefully sprayed for scab:

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[1] "Resistant" as used in this publication means less susceptible than most other varieties. It does not mean that the variety is entirely free from or immune to the trouble indicated.

[2] Meaning of colons, stars and daggers is explained on page 16.

Wealthy*†.—Erect grower, very hardy and probably better adapted to colder sections. Bears young, usually bi-ennially and heavily; fruit of good size and excellent appearance on young trees, but becomes under-sized on old ones unless strongly thinned or renewal-pruned. On heavy soils the fruit may become too soft for ordinary shipping even before coloring. Good for dessert or cooking.

Late Autumn and Winter Varieties.

Smokehouse.**—M.[1] Vigorous grower and satisfactorily productive, forms very tangled and dense head, with more or less drooping branches, and hence needs rather high heading and careful pruning and spraying. Also needs plenty of space in the orchard. Fruit in its prime is of high quality and generally of good size, but color is usually dull and therefore needs to be known in order to sell well on the open market:[1]

Hubbardston†.—L to M. Variable on different soils. Apt to require thinning to keep up size and normal development. Extremely susceptible to borers, especially on light soils; hence requires special protection either by means of proper coverings or possibly by top-working. Fruit large, often subject to dropping in absence of sufficient moisture, and shrivels in storage. Good in quality and appearance.

Grimes*.—M to H. Fruit unexcelled in quality and of good appearance if carefully handled. The tree, however, has a weak root-system, is very susceptible to collar blight or other diseases of the trunk and, hence, in many parts of the state is short lived, a difficulty which may be overcome by top-working on a more vigorous stock. With this defect remedied and with proper soil and good care it is fully commercial. In top-working it is probably advisable to select cions from best individuals:

Jonathan*†.—L. Fully commercial under proper soil conditions and care. It has unexcelled appearance, highest quality, early and abundant bearing and brings top prices in its season. Best on a light, deep, mellow loam or upon a sandy loam with retentive subsoil, and good air drainage. Its chief faults are fruit spot, which is especially bad some seasons, and a tendency to run small, especially on old trees, unless properly thinned and cultivated. The fruit spot is probably preventable with a fungicide applied about July 1.

Rome Beauty*.—L to M. Has done very well in adjoining states and is reported to be growing in favor in some parts of Pennsylvania. Under right conditions it is probably of commercial value especially in the southwestern section. In some parts of the state the writer has observed it to be lacking in quality and appearance, especially when found on too heavy or poorly drained soil.

Wagener†.—(See discussion in list for northern Pennsylvania).

York Imperial.**— M to H. Originated in York County and very widely grown. Moderately early bearer, and very productive; decidedly biennial, a habit that may be lessened by heavy thinning and fertilization on the full year. Fruit attains very fine appearance and a good quality if permitted to mature properly on the trees. Excellent for cooking, immature specimens being only valuable for that. Resistant to scale but rather susceptible to blight. At present the tendency in planting seems to be turning toward higher-qualitied varieties, though this is a money-maker if properly handled:

Gano.—This variety together with Ben Davis, of which it is a strain, is an early bearer, and produces fruit of fine appearance and excellent keeping and shipping qualities. Quality and reputation on market are low, however, and it is very susceptible to injury by scale, curculio and codling moth. For these reasons, its commercial planting as well as that of Ben Davis is much less active than formerly:

Stayman Winesap.**—M. Probably now being planted more than any other variety in southeastern Pennsylvania and adjoining states. Much larger than the old Winesap, though not so well colored. Tree very vigorous and rather early bearer. Its size, high quality and long keeping bring for it high prices, especially on the Philadelphia market. Season December to May.

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[1] For meaning of letters, colons, stars and daggers see page 16.

B. Varieties for Northern Pennsylvania and the Higher Altitudes in Central Pennsylvania.[1]

Summer Varieties.

Yellow Transparent†*: Red Astrachan*.—(Varieties discussed above).

Oldenburg (*Duchess*) **†.—These three varieties are among the best early commercial for this section, though none are good for dessert. Williams is likely to prove among the most satisfactory for the latter purpose, though its trial in this section is too limited for definite recommendation.

Early Autumn Varieties.

Chenango.—A beautiful, high-quality apple, well recommended for home and local market but too tender for ordinary shipping. Tree reported early and regular in bearing, and relatively free from disease, but is under size and a poor grower.

Alexander.—A large, coarse, well colored apple of Russian origin, and low quality, for which there seems to be some demand on certain markets. Tree is hardy and moderately productive. Possibly limited commercially near good markets.

Gravenstein*: Maiden Blush*: Wealthy†*.—(See discussion of these varieties in list for southern Pennsylvania).

Late Autumn and Winter Varieties.

Twenty Ounce.—Usually meets a good market demand on account of large size and good cooking qualities. Tree medium size, poor grower, with dense, erect top unless carefully pruned. Reported subject to sunscald, blight and canker and also to spray injury. Sports of this variety, known as Collamer and Hitchings, are better colored.

Fall Pippin*.—One of the most desirable of its season for the home orchard and of much value commercially in a number of locations in the state. Tree very vigorous and long lived, of spreading habit and eventually somewhat drooping. Fruit large and attractive; ripens over a long season; rather susceptible to scab, both in fruit and foliage.

McIntosh*†.—A very handsome and high quality apple of the Fameuse or Snow type, but larger, redder, and apparently more widely adapted. Subject to scab unless properly sprayed. Bears rather young but requires careful growing. Reported among the best commercial varieties of its season in the higher altitudes of northeastern Pennsylvania. Sells very well in most markets:

Hubbardston†: Smokehouse*.—(Discussed above). Smokehouse is less valuable toward the northern limits of this section.

Tompkins King.—M. Large, high-quality, good appearance, and often brings highest prices on New York markets; but tree is short-lived unless top-worked on a more hardy kind, and is only fairly productive.

Northern Spy.**—At present widely known in northern Pennsylvania, where it succeeds well especially on the higher altitudes. Its chief faults are tardiness in bearing and susceptibility to attack from blue mold, which produces a soft rot of the fruit unless properly handled at picking time. Its vigor of growth, high quality and regular and abundant bearing with age are likely to keep it a favorite for some time, however, though the faults named are undoubtedly a considerable handicap to new plantings.

R. I. Greening*.—M to H. Excellent both for cooking and dessert. Varying reports of its value in northern Pennsylvania are received, the difference being probably due to local conditions and handling. It is valuable under right conditions of soil and care.

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[1] Varieties merely named here are discussed above, their starring being more or less modified. Order of ripening and meaning of colon (:), stars (*), etc., are as indicated on page 16.

Wagener†.—One of the earliest to come into bearing and of rather dwarfish form, hence considerably used as a filler, for which it is very good. Properly grown fruit is of high quality but it is usually quite variable in size, and hence often requires thinning of the smaller apples, which are of little value.

Esopus (*Spitzenburg*).—Of excellent quality and good reputation on the general market but of doubtful value for anything but the home orchard in Pennsylvania. Tree slow grower at first, and rather subject to canker and collar blight; only moderate cropper; requires a fertile, moist soil though not one that is over-wet. Apparently the parent of Jonathan.

Baldwin..**—M to L. Most planted and generally most profitable in the older orchards of northern Pennsylvania. On the proper soil it is well adapted to the northern part of the state and is favorably reported in the higher altitudes even of the southern part. In the lower altitudes of the latter section it becomes a fall apple and is surpassed by other varieties. Rather tardy in bearing, but prolific with age, and a standard apple on the market.

Stayman Winesap*. — M. Probably not so well adapted to the northern section of the state as some other varieties, though this can doubtless be determined locally from plantings already made. The most risk is incurred in its planting in the higher altitudes and northern counties. See its discussion in a preceding section:

Lankford.—Apparently of the general type of York Imperial though not oblique; has been favorably reported from the western end of the state and also from the southeastern part. It is said to be a good bearer (on Volusia silt loam), and to be equal or superior to Baldwin in quality and to Ben Davis in keeping.

Roxbury (*Russet*).—H. Long keeper, but subject to shriveling; of good though not high quality. Usually a satisfactory cropper, especially in the higher altitudes of the northern part of the state, and occasionally very productive when properly cared for and on the right soil. Season from December to May.

C. Varieties Worthy of Limited Trial.[1]

Magnate (*Magnet*).—Of similar origin and type as the Stayman Winesap, but more highly colored and earlier. Probably well adapted to the southern part of the state. Season about with Jonathan, and on medium or heavy soils it is doubtless preferable to that variety. Fruit medium to large; prevailing crimson red, indistinctly striped with dark purple and usually covered with whitish bloom. Tree reported to be an upright, open grower requiring little pruning.[2]

Banana (*Winter Banana*).—Resembles Maiden Blush in appearance but is later, being in season about with R. I. Greening. Of Indiana origin, quite successful in the far west and favorably reported east. Fruit is large, somewhat irregular in size; characteristically aromatic; clear, pale yellow, with a pinkish red blush and often with suture lines; very good for dessert but too mild for best culinary use. Tree of medium size with a rather flat, open and spreading habit of growth; rather subject to blight.

Delicious.—Originated in Iowa about 1881, from the stock of a Yellow Bellflower.[3] Especially good in the far west. Fruit dull red with darker stripes over a greenish yellow ground; very mild, sub-acid, aromatic and very good. Like Banana, it is rather tender textured and hence requires careful packing for best results. Tree hardy, strong, upright and apparently sufficiently productive for commercial use, Fruit reported small in the East.

King David†.—Apparently of the Winesap group and hence likely to do best in the southern part of the state; originated in Arkansas. Fruit of medium size, fine appearance and reported to be of high quality. Color a rich red with darker stripes, over a yellow ground. Tree is said to be a strong vigorous grower, and early bearer. Recommended by some in preference to Jonathan, though it is later.

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1. Named in order of ripening.
2. See U. S. Department of Agriculture Yearbook, 1906:255-257.
3. See U. S. Department of Agriculture Yearbook, 1907:305-307.

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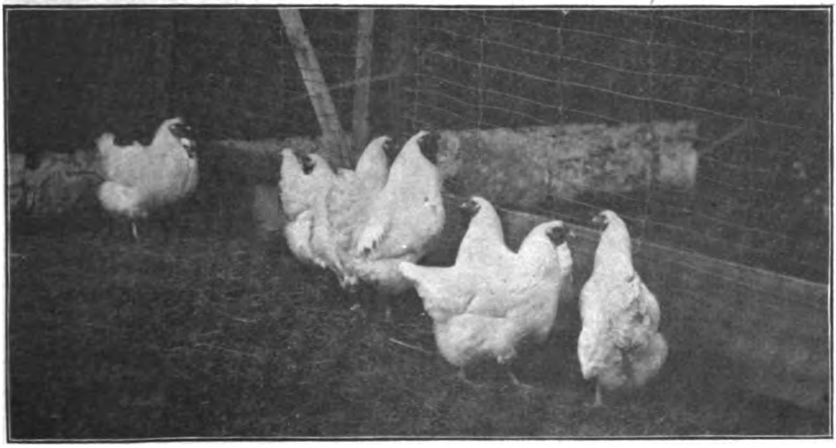
The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 107



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† Assigned by the Bureau of Soils, U. S. Dept. of Agr.

The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 107

POULTRY EXPERIMENTS AND MANAGEMENT

T. I. MAIRS and H. W. JACKSON

SOME POULTRY EXPERIMENTS

T. I. MAIRS

Summary of Bulletin No. 87

Observations on the growth of chicks of different breeds kept under similar conditions were made during the summer of 1906 and again in 1907. A comparison of wet and dry mash was made at the same time. The mash used in 1906 was mixed in the following proportions:

50 pounds corn meal,
15 pounds of gluten feed,
7½ pounds alfalfa meal,
25 pounds wheat bran,
5 pounds oil meal,
13 pounds animal meal.

In 1907 the mixture was as follows:

20 pounds corn meal,
25 pounds ground oats,
10 pounds ground buckwheat,
10 pounds ground millet seed,
10 pounds ground barley,
15 pounds ground Kaffir corn.

At the close of each feeding test typical animals of the different breeds were slaughtered to determine loss in dressing, drawing, etc.

Incubation tests were also made. All eggs were weighed and chicks were weighed as soon as hatched.

A test of forced moulting was made in 1907.

The conclusions drawn from these experiments, which were published in detail in Bulletin 87, now out of print, are published herewith as a sort of introduction to the feeding experiments of 1908.

CONCLUSIONS.

1. Large breeds in general eat more than small ones during the growing period.

2. Early hatched chicks grow faster than late hatched ones. April 1st seems to be a desirable time for hatching in this latitude.

3. The amount of feed required to produce a pound of gain increases as the chicks approach maturity.

4. Between the ages of six and thirteen weeks, there were required from four to four and three-quarter pounds of feed to produce a pound of gain. Between the ages of thirteen and twenty-six weeks, there were required from four and three-quarter to five and three-quarter pounds of feed to produce a pound of gain.

5. Chicks forced when young do not make so rapid a growth, as they approach maturity, as those fed a more moderate ration.

6. Chicks weighing less than one pound seem to grow faster on a wet mash; those weighing a pound and a half or more do best on dry feed.

7. The loss among chicks on wet mash was much greater than among those on dry feed, even when weighing less than one pound each.

8. The slaughter tests indicate that the American breeds dress out better than either the Mediterranean or Asiatic breeds, and that in general pullets dress out better than cockerels. When rather small, weighing less than three and a half pounds live weight, the cockerels of the Mediterranean and Asiatic breeds seem to dress out better than the pullets.

9. Forced moulting seemed to first depress, then increase slightly, egg production, but the net results at the end of three months were against forced moulting.

10. Eggs set about April 1st seemed to produce the highest per cent. of chicks.

11. The eggs of the different breeds in order of their weight were as follows: Black Minorca, Light Brahma, Barred Rock, White Leghorn, White Wyandotte, Rhode Island Red, White Crested Polish, Buff Cochin. A great deal may depend upon the strain, as it is known that some hens of any breed normally lay larger eggs than others of the same breed.

12. The weight of chicks when hatched does not seem to be in direct proportion to weight of eggs.

FEEDING GROWING CHICKS, 1909.

June 14, 1909, two hundred chicks of about the same age were weighed and divided into four lots as described below. All had been hatched and brooded artificially and had been without heat from one to two weeks.

Lot I. Fifty White Leghorns fed a wet mash three times a day in a yard which had been plowed and sown to oats and Dwarf Essex rape.

Lot II. Sixteen Barred Rocks and twenty-four R. I. Reds fed a dry mash from hopper in yard similar to Lot I.

Lot III. Fifty White Leghorns fed a dry mash from hopper in yard similar to Lot I.

Lot IV. Fifty White Leghorns fed a dry mash from hopper in a yard of sod composed of timothy, white and red clover, with some plantain and Shepherd's purse.

The mash fed to all four lots consisted of a mixture in the following proportions:

Cracked corn	4 lbs.
Pin-head oats	2 "
Shredded wheat waste	3 "
Beef scrap	1 "

Grit and oyster shell were kept before all lots constantly. After July 2d cracked wheat was substituted for shredded wheat waste.

The grass and clover from the yard in which Lot IV was placed had been cut and raked off June 10. The oats in the other three yards were about four inches high and the rape had four to six leaves.

All lots were housed in low colony houses about 4 ft. x 8 ft.

The following table shows the growth during the first six weeks:

WEIGHT OF CHICKS.

	Lot I—Lbs.	Lot II—Lbs.	Lot III—Lbs.	Lot IV—Lbs.
June 14	19.00	16.00	17.00	17.50
June 22	26.50	26.00	19.00	21.00
June 28	32.00	35.00	23.00	26.00
July 5	35.00	42.50	31.50	32.50
July 12	46.50	51.50	36.00	38.00
July 19	51.50	58.25	41.75	43.75
July 26	61.00	66.25	47.50	51.00
Gain	42.00	50.75	30.50	33.50
Chicks lost	2	0	3	3

From this it appears that the Leghorn chicks on wet mash made about 40% better gains than those on dry mash and those on sod made slightly better gains than those on cultivated ground. The Barred Rocks and the Rhode Island Reds made about 66% better gains than Leghorns under the same conditions. Only two chicks are known to have died during this time, one each in Lots III and IV. The others missing from Lots I, III and IV are thought to have escaped from the yards.

July 26, the cockerels were removed from Lots I, III and IV, leaving twenty-eight pullets in Lot I and twenty-five pullets each in Lots III and IV. August 9th the cockerels were taken out of Lot II, leaving twenty-four pullets.

The following table gives the weight for the next four weeks:

	Lot I—Lbs.	Lot II—Lbs.	Lot III—Lbs.	Lot IV—Lbs.
July 26	34.25	66.25	24.25	26.25
August 2	40.25	74.75	25.25	30.50
August 9	44.75	44.75 a 39.75 b	31.75	35.00
August 17	50.50	47.50	37.00	40.50
August 24	54.25	54.00	40.75	43.25
August 31	59.00	56.50	45.50	44.50
Gain	24.75	16.75 c	21.25	18.25
Chicks lost	0	0	0	0

a...26 cockerels, b...24 pullets, c...three weeks' gain only.

Again the Barred Rocks and the Rhode Island Reds outgrew the Leghorns and the Leghorns on wet mash outgrew those on dry feed.

The following table shows the feed eaten each week by the different lots:

Week Ending	Lot I Lbs.	Lot II Lbs.	Lot III Lbs.	Lot IV Lbs.
June 21	24.25	31.00	18.00	19.00
June 28	26.00	27.00	21.00	21.00
July 5	30.25	36.00	23.50	23.50
July 12	37.00	34.00	28.00	28.00
July 19	31.50	35.00	27.00	27.00
July 26	30.00	35.00	24.00	24.00
First six weeks	179.00	198.00	141.50	142.50
Aug. 2	a20.25	47.00	b20.00	b20.00
Aug. 9	18.75	41.00	17.00	20.00
Aug. 16	19.75	c17.00	13.00	13.00
Aug. 23	18.25	18.00	9.00	10.00
Aug. 30	19.00	20.00	17.00	15.00
Last five weeks	96.00	d55.00	76.00	78.00

a 28 pullets from August 2nd.
b 25 " " " "
c 24 " " " "
d 3 weeks only.

During the first six weeks, there were required 4.26 pounds of feed to make a pound of growth on Lot I, 3.90 pounds on Lot II, 4.64 pounds on Lot III, and 4.25 pounds on Lot IV. During the last five weeks there were required 3.88 pounds of feed to make a pound of growth on Lot I, 3.57 pounds on Lot III, 4.27 pounds on Lot IV, and on Lot II, during the last three weeks, 3.57 pounds of feed were required to make a pound of gain. The fact that a smaller amount of feed was required during the latter part of the test may be due to the greater amount of forage furnished by the yards incident to the ripening of the oats.

These results confirm those of former tests, viz., that chicks grow faster on wet mash than dry of the same composition. In a former test, however, there was greater loss on the wet mash. In this test the loss was about the same in each lot.

CRATE FATTENING.

October 27th, 1908, two lots of chickens, sixteen each, were put in crates for fattening. One lot was bought from a farmer and consisted of Grade Barred Rocks, thin in flesh. The other lot consisted of one Barred Rock, two Rhode Island Reds, four White Wyandottes and nine white Leghorns. All the chickens were fed a mixture of wheat, bran, corn, chop and wheat middlings, three pounds of each, with one pound of beef scraps. The following table gives the record of the two lots:

	Lot Bought	Lot Raised
Weight at beginning	53.0 lbs.	38.00 lbs.
Weight at end of three weeks	63.75 lbs.	46.00 lbs.
Gain in live weight	10.75 lbs.	8.00 lbs.
Pounds of feed eaten	105.00 lbs.	60.00 lbs.
Dressed weight	48.00 lbs.	35.25 lbs.

A lot of twenty-four White Leghorn cockerels and one black Minorca was put in crate for fattening July 1, 1909, and fed three weeks with the following results:

Weight at beginning	31 lbs.
Weight at end of three weeks	44 lbs.
Gain in live weight	13 lbs.
Feed eaten	74 lbs.
Dressed weight	35 lbs.

The gain in weight is but a small part of the benefit of crate fattening. The most important benefit is the improvement in the quality of the flesh which unfortunately cannot be directly expressed in figures.

HATCHING AND RAISING CHICKS.

HOMER W. JACKSON

Hatching with Hens.—When hens are used for hatching, it is desirable to keep them in separate rooms, protected from disturbance. The room should be convenient, rat-proof and on the ground floor if possible, though a mow or second-story room will answer. Hens should be moved at night to the setting-room, placed upon nests carefully prepared beforehand, and given a few infertile eggs until they have become accustomed to the surroundings. Hens may be set in large numbers in these rooms and managed quite economically if the work is done in connection with other chores. It is desirable that all nests be of the same pattern. These nests are conveniently made in sets of two and three, located around the walls of the room in tiers, one above another. Figure I shows the type of nest used at this Station and the method of arrangement. From fifty to one hundred hens may be set in one room, by this method, and if carefully handled will do as well as if there were only a few. When a considerable number of hens are sitting, they should be fed and watered in groups of

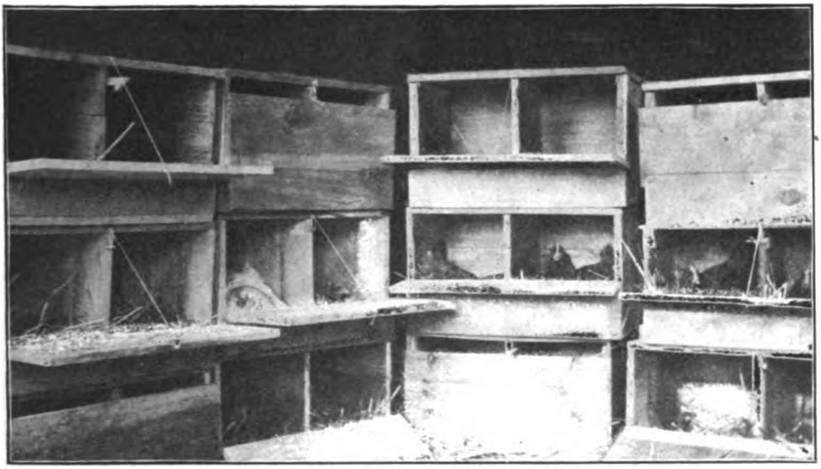

Fig. I.—Nests for Setting Hens, Showing Method of Arranging Them in Tiers to Economize Room.

six to twelve each, returned to their nests after a sufficient time, and another group let off. Except when the hens are off for exercise once a day, the nests are kept closed. The room should be darkened and, in warm weather, kept as cool as possible. Cracked corn, green feed, grit, a crock of water and a dust bath are all that need be provided. The sitting hens should be dusted with insect powder or lice killer when set, and again two or three days before hatching. In cold weather, thirteen eggs are sufficient for even a large hen. In warm weather, the number may be increased.

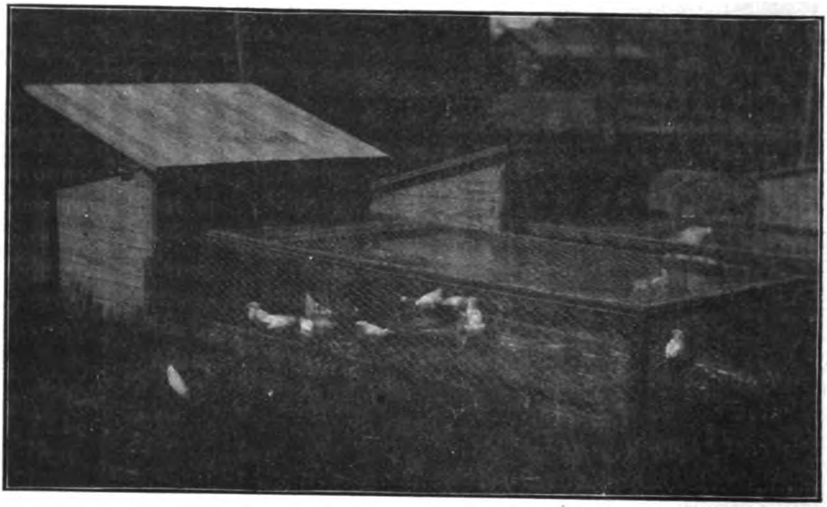

Fig. II.—Brooding Coop and Covered Run.

Hatching with Incubators.—When chicks are hatched in large numbers, or early in the season, and where non-sitting breeds are kept, incubators are indispensable. There are many different types of incubators on the market, most of which will give excellent results under certain conditions, but there is no way of determining which type is best suited to different localities and individuals. It is desirable, if possible, to buy incubators on trial. The instructions accompanying incubators should be thoroughly mastered and carefully followed. This Station issues a circular on Incubator Management which will be sent free on application.

RAISING CHICKS.

When chicks are raised with hens, a brood coop, such as is shown in Fig. II, will be found to be very satisfactory. This coop may be 2½ feet x 3 feet and 2 feet high in front. It should have a hinged top, providing easy access to the interior. It is desirable to provide these coops with covered runs in which the chicks may be kept during the first few weeks. These runs protect the chickens from straying and being caught in storms, and also from their many enemies. Chicks will do as well in these runs at first as on range and the losses will be much smaller. Brood coops with board floors and runs are especially valuable where there is danger of gapes. The coop and run should, however, be shifted to new ground very frequently.

Generally, the most satisfactory way of brooding chicks artificially is with indoor brooders, located in colony brood houses. Brooders must be managed with extreme care during the first few days of the chicks' lives in order that they may not be chilled or overheated. It is desirable to get the chicks on the ground as soon as possible but nothing is gained by letting them out until they have learned the use of the hover. Brooders should be provided with runs and the chickens confined to them until they are large enough to be turned out on the range. They should be moved to new ground, frequently, and be kept clean and sanitary. There is danger of fire with all brooders and it is not wise to locate them in valuable buildings or in close proximity to them.

Feeding.—Young chicks are raised on all kinds and combinations of feeds and success is, in the last analysis, more a matter of care than feed. The common practice of using cornmeal dough, while comparatively successful sometimes, is not to be recommended and its use is not likely to secure the best or most rapid growth and development of the chicks. Probably the most satisfactory ration for young chicks, for the first few meals, is bread moistened with milk or water and squeezed dry. A small amount of grit or sharp sand may be mixed with the bread. An ample supply of chick-grit is always desirable in feeding young chicks. It may be mixed with the feed or spread on the floor of the coop or run. After the first few days the bread may be omitted and a mash, somewhat similar to the mash fed to the laying hens, may be given morning and evening with two or three feeds of finely cracked grains or chick feed during the day. Cracked corn, cracked wheat and pin-head oats mixed in equal proportions make a fairly satisfactory grain mixture. Much care must be exercised in feeding young chicks the first few days. At least one-half of the ration should be small grains scattered in straw or chaff so that the chicks may secure some exercise. Green feed should be supplied daily. For this purpose, lettuce, chopped onion tops, green clover or grass are excellent and when these are not available mangles or potatoes will give good results. After the chicks are weaned and turned out on the range, hopper feeding may be adopted with good results. Nothing is gained by stinting growing chicks. They should have all the feed that they can be induced to eat. Hoppers or low boxes, divided into compartments and supplied with mash, cracked wheat or corn, meat scrap or grit, may be kept before them after they have reached six or eight weeks of age, with perfect safety. In addition to the feed in the boxes, it is often desirable to give one feed of wet mash a day and possibly a feed of some kind of grain other than that kept in the hoppers.

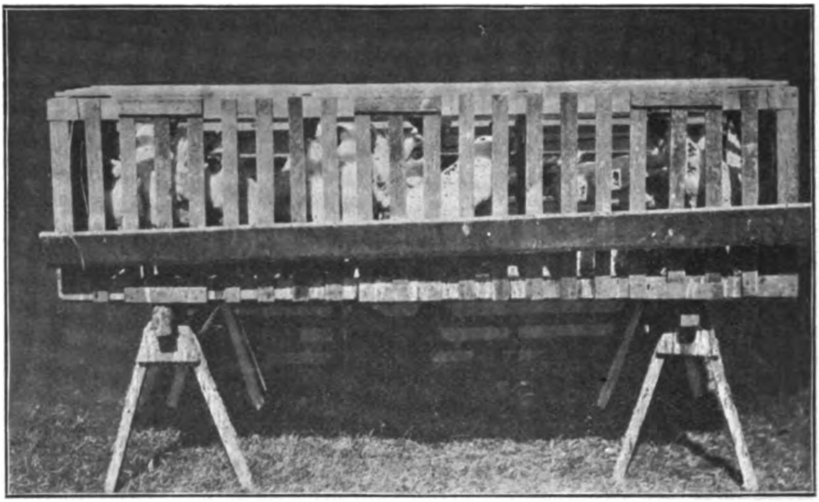

Fig. III.—Fatting Crates.

Care should be taken that the chicks do not become crowded in brooders or coops, and as they grow larger coops should be provided or the size of the flocks reduced from time to time. Many flocks of young chickens are delayed in maturity or stunted in growth from crowding in coops or brooders at night. With the exception of Leghorns, there is no particular gain in separating the sexes of the growing flocks until the male birds are to be fatted for market. At this time a separation should be made as it is not desirable to give the same ration to growing pullets and market stock.

Fattening.—The most satisfactory way to fatten chickens is to confine them in fattening crates three or four weeks before they are to be sent to market. Fig. III illustrates one of the fattening crates used at this Station. It is six feet long, eighteen inches wide, twenty inches high and divided into three compartments, each of which holds from three to five birds. In making these crates, slats about 1½ inches wide and 1 to 1½ inches in thickness are used. Those in front are nailed on perpendicularly, two inches apart, allowing the fowls access to the feed trough. These crates may be placed out of doors in warm weather with slight protection. In cold weather they should be placed in a shed or a house. A V-shaped trough is hung to the front of the crate by wires, for feeding. Care should be taken that the birds are not over-fed for the first few days. After they have become accustomed to the change and the ration, they should have all they want to eat. Usually two feeds a day are all that can be given in winter, but in summer a third feed may be given. Chickens of all sizes may be fattened in these crates and sent to market in best possible condition. In fattening, the common ration of cornmeal is rarely as satisfactory as a combination of grains. An excellent mixture is equal parts of finely ground cornmeal, buckwheat and oats with the hulls removed. A ration of one to two parts cornmeal, one part middlings and 5 per cent. meat scrap may be used if it is not possible to secure the other grains. It is important, whatever grains are used, that they be finely ground. If this ration is mixed with sour milk, no animal food will be needed. If mixed with water, a small portion of meat scrap or other animal food should be added. The ration should be mixed just thin enough to pour from the feed bucket. Green feed should be given at least every other day and grit occasionally. Feed should not be allowed to remain before fattening birds and any remaining after the fowls are through feeding should be promptly removed.

It is doubtful whether crate-fattening for the ordinary market will pay for the labor involved. If discriminating purchasers cannot be secured, it will probably be more profitable and less laborious to fatten the fowls in pens, with or without yards, though it is not probable that this method will produce as great gains or flesh of as high quality.

DISEASES OF YOUNG CHICKS.

Diarrhoea.—By far the most important trouble affecting young chicks is diarrhoea. This is not, strictly speaking, a disease but a symptom accompanying several disorders. In a general way anything that unfavorably affects the health and vigor of the chicks will produce it. Diseased breeding stock, improper methods of incubation and brooding, improper feeding, too much or too little heat or insufficient exercise may produce it. The best preventive is careful attention to these details. Incubators, nests, coops and brooders should be thoroughly disinfected. Frequently it is possible to relieve the trouble and check its spread by feeding boiled rice and scalded milk, but the diseases producing diarrhoea have not been sufficiently investigated to make it possible to prescribe positive remedies.

Gapes.—Gapes is caused by the presence of gape-worms in the wind-pipe of the chicken. Infection is from the ground and when any location is known to be infected it is unwise to attempt to raise chickens upon it. Either a new location should be secured where there is no infection or chicks should be kept on board floors until danger is past. Probably more infection occurs through the fish-worm than any other source. To correct a general misapprehension it should be explained that fish-worms do not cause gapes unless they come from infected soil. There is no known practical means for combating soil infection. It is desirable to use lime and other disinfectants about coops and runs, but as far as is known there is no way of exterminating the gape-worm after the soil has become infected except by keeping the chicks off of it entirely for a year or two. For affected chicks, a twisted horse-hair, or some similar contrivance for extricating the worms, is probably most effective. Rubbing the outside of the throat with lard and turpentine and dropping a little creolin into the windpipe sometimes effect cures.

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BULLETIN No. 108

VARIETY TESTS OF OATS

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
FEBRUARY, 1911

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The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 108

VARIETY TESTS OF OATS

F. D. GARDNER and J. A. RUNK

For twenty years, the Pennsylvania Experiment Station has been testing varieties of oats, the results of which have been published from time to time in [1]Bulletins and [2]Annual Reports. The object of these tests has been to ascertain the relative productiveness of well known varieties as well as those of recent introduction when grown under uniform conditions. Varieties that fail to compare favorably in yield with the standard varieties, as a result of three or four years tests, are dropped from the list and give place to other varieties. A small number of the best varieties are grown for a long series of years, as a standard for comparison with those of recent origin or introduction.

Soil, Treatment and Rotation.

The soil on which the trials are made is Hagerstown clay loam, and is typical of the soil of the Station farms as well as the soil of the limestone valleys of Pennsylvania. For many years, it has been devoted to a four years' rotation, consisting of clover and timothy, potatoes, oats, and wheat, each one year. The land is in four equal plats, so that the oats are on a different plat each year and always follow potatoes.

The ground is manured for both potatoes and wheat at the rate of 7 to 10 tons of yard manure per acre, and both the oats and wheat are fertilized with acid phosphate at the rate of 160 pounds per acre. This maintains a high state of fertility, so that average yields per acre are: Hay, three to four tons; potatoes, 160 bushels; oats, 55 bushels; and wheat, 32 bushels.

Test in 1906.

The ground was harrowed April 20, and 21. The oats were sown April 21, at the rate of two bushels per acre. Acid phosphate was applied at the rate of 160 pounds per acre and then the ground was rolled. The seed bed was in excellent condition.

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[1] Bulletins Pennsylvania Experiment Station Nos. 39 and 76.

[2] Annual Reports Pennsylvania State College, years 1900, 1903, 1905 and 1908.

Two drill widths of each variety were sown in a plat, and duplicate or triplicate plats of each variety were sown. The yield for each variety in the following table is the average of two or three plats, as the case may be. Each plat was twelve feet wide by 134 feet long and comprised .0396 acre. The oats were cut July 23, and 24 and threshed July 31. The season was unfavorable for oats and the yields were low.

Test in 1907.

The ground was plowed March 30. It was harrowed twice April 18, and once April 25, with a spring-toothed harrow. The oats were sown April 25, at the rate of 10 pecks per acre; and dissolved rock at the rate of 160 pounds per acre was applied. The oats were rolled May 21.

The oats yielded well this year, the average being about twice as great as in 1906.

The oats were cut August 3, and threshed August 7 and 8.

In the table which follows, there are given the yields of grain and of straw and the weights per struck bushel in 1906 and 1907. These are the averages of the yields from the different plats of the same variety.

Yield of Varieties.

No.	Variety	1906			1907		
		Grain per acre, bushels of 32 lbs.	Straw per acre pounds	Weight per struck bush'l pounds	Grain per acre, bushel of 32 lbs.	Straw per acre pounds	Weight per struck bushel pounds
1	Japan	35.3	1,768	33.8	65.3	4,418	31.5
2	Big Four	28.9	1,988	34.5	64.4	4,172	34.0
3	Czar of Russia	30.1	1,395	32.8	64.0	3,993	34.0
4	Sensation	23.6	1,164	34.0	61.3	3,889	32.5
5	White Maine	32.2	1,316	32.7	61.9	3,869	34.0
6	Long's White Tartar	24.6	1,020	36.2	64.0	3,485	34.5
7	White Russian	21.0	1,321	33.3	56.4	3,539	33.0
8	Irish Victor	29.5	1,561	33.0	64.0	3,867	30.0
9	Heavy Weight Champion	33.7	1,578	32.0	63.2	3,829	31.5
10	Fourth of July	34.0	1,623	32.5	62.7	3,655	30.5
11	Golden Fleece	26.1	1,426	34.8	61.1	3,323	32.5
12	Great American	30.4	1,716	34.0	63.8	4,255	31.5
13	Silver Mine	27.8	1,521	34.3	65.9	3,870	32.0
14	Golden Giant Side	26.3	1,138	32.0	55.6	3,883	32.5
15	Liberty	31.0	1,582	33.3	60.4	4,172	32.0
16	New Danish White	30.4	1,398	34.3	64.3	3,921	33.0
17	Probsteier	27.9	1,305	32.8	62.0	3,676	33.0
18	Lincoln	28.9	1,392	33.3	61.3	4,356	32.0
19	Mortgage Lifter	25.6	1,104	33.8	53.9	3,194	34.0
20	Joanette	....	.....	....	63.2	4,338	33.0
21	Siberian	....	.....	....	57.9	3,807	35.0
22	Sixty Day	....	.....	....	68.7	2,890	33.0
23	Swedish Select	....	.....	....	61.0	3,962	38.5

Test in 1908.

The ground was plowed April 17, and harrowed April 24 and 27 with a spring-toothed harrow. The oats were treated for smut April 22 with formalin, 1 pint 40 per cent. formalin to 30 gallons of water, for 25 minutes.

They were sown April 27. The drill was set to sow 11 pecks per acre, but the oats were somewhat swollen from having been wet, and so the rate of seeding was about 10 pecks dry oats per acre. Dissolved rock was applied at the rate of 160 pounds per acre.

Instead of sowing duplicate plats as formerly, Japan was used as a check variety and sown on every third plat, and then only one plat of each of the other varieties was sown. Each plat was 142¼ by 12 feet, and comprised .0392 acre.

The oats came up well, and the fore part of the season was very favorable, but the crop was injured by the drought in July. No smut appeared where the seed was treated with formalin, but all the varieties were considerably injured by rust.

All the varieties were cut July 27 and 28, except Sixty Day which was cut July 20. They were all threshed July 31.

In the following table there are given the actual yields, the corrected yields and the weight per struck bushel. In computing the corrected yields, we assume a gradual increase or decrease in fertility from one check plat to the next in the usual way.

The average yield of all check plats is taken as the correct yield for Japan. To get any other variety to the same basis, we assume that the actual yield of the variety in question should be increased or reduced in the same proportion that the check variety, if grown upon the same plat, would be increased or reduced, in order to equal the average yield of all check plats. We also assume that the variation in fertility of the land, as indicated by the check plats, is a uniform gradation from one check to the next. For example, Japan, on plat 1, gave 44.6 bushels and, on plat 4, gave 46.3 bushels. If sown on plat 2, it is assumed that it would have given 45.2 bushels per acre. The average yield of Japan was 49.5 bushels per acre. Then, the corrected yield of Big Four would be found by the following proportion: 45.2, the assumed yield of the check variety, if sown on plat 2, is to 49.5, the average yield of the check variety, as 44.5, the actual yield of Big Four, is to x, the corrected yield of Big Four. That is—$45.2:49.5::44.5:x$. Therefore $x=48.7$. Without correcting in this way, the actual yields of varieties are not strictly comparable, because of the variation in the fertility of the soil.

Yield of Varieties—1908.

No.	Variety	Actual Yields per Acre		Corrected Yields per Acre		
		Grain bushels 32 pounds	Straw pounds	Grain bushels 32 pounds	Straw pounds	Weight per struck bushel pounds
1	Japan	44.6	2,528	49.5	1,886	33.8
2	Big Four	44.5	1,314	48.7	1,165	34.4
3	Czar of Russia	40.3	1,929	43.6	2,109	35.5
4	Japan	46.3	1,324	....	.....	....
5	Sensation	41.5	1,092	43.0	1,242	34.7
6	Joanette	51.5	1,758	51.7	1,664	36.2
7	Japan	50.8	2,327	....	.....	....
8	Siberian	50.4	1,602	47.3	1,457	34.9
9	Sixty Day	55.0	1,536	49.8	1,593	32.3
10	Japan	56.7	1,566	....	.....	....
11	Swedish Select	44.6	1,620	39.7	1,665	35.5
12	White Maine	39.4	2,349	35.6	2,104	32.7
13	Japan	53.4	2,375	....	.....	....
14	Long's White Tartar	45.8	1,255	44.2	1,015	36.2
15	White Russian	47.1	1,918	45.6	2,049	34.8
16	Japan	50.0	1,459	....	.....	....
17	Irish Victor	45.6	1,130	45.3	1,296	34.3
18	Heavy Weight Champion	42.2	1,242	42.2	1,291	33.8
19	Japan	49.3	1,992	....	.....	....
20	Fourth of July	45.3	1,087	45.9	1,163	33.8
21	Golden Fleece	42.9	1,408	44.0	1,408	35.5
22	Japan	47.8	1,278	....	.....	....
23	Great American	43.4	.....	43.9	.....	33.4
24	Silver Mine	45.2	1,472	44.6	1,299	34.9
25	Japan	51.3	2,569	....	.....	....
26	Golden Giant Side	47.4	1,602	45.2	1,293	33.9
27	Liberty	46.4	2,066	43.8	1,942	29.8
28	Japan	53.0	1,875	....	.....	....
29	New Danish White	47.0	1,610	45.8	1,632	30.4
30	Probsteier	47.4	1,847	48.3	1,887	31.1
31	Japan	46.4	1,832	....	.....	....
32	Lincoln	46.9	1,834	50.7	2,005	32.7
33	Mortgage Lifter	43.0	1,798	47.1	2,097	34.6
34	Japan	44.6	1,510	....	.....	....

Test in 1909.

The seed of the varieties was treated for smut April 6, with formalin solution in the usual way.

The ground was plowed April 8, harrowed and rolled April 12 and 13, and the varieties were sown April 13. Oats were seeded at the rate of nine pecks per acre. Acid phosphate was applied at the rate of 160 lbs. per acre. Each plat was 133 by 11 feet, and comprised .0341 acres.

Japan was used as a check variety and was sown every fourth plat.

The season was favorable during the growing period, but some of the varieties were lodged by rain storms of July 14 and 15. No smut was found on the varieties which were treated with formalin, while the general crop which was not treated was estimated to have 1% of the heads infected. Considerable blade-blight developed on the varieties this year, and late in the season a large amount of rust also developed. It is possible that the rust resulted from the weakening of the plants by the blight. A considerable quantity of blasted heads developed, probably from the same cause.

Kherson and Sixty Day varieties were cut July 12, and the remaining ones on July 27, except Golden Giant Side, which was cut on July 30. All varieties were threshed August 3.

The largest corrected yield of grain, 63.6 bushels per acre, was produced by Kherson, a variety maturing in 90 days from the date of seeding or 15 days earlier than the medium maturing varieties. The lowest corrected yield, 45.5 bushels, was produced by Golden Giant Side, the latest maturing variety in the list.

Yield of Varieties—1909.

No.	Variety	Actual Yields per Acre		Corrected Yields per Acre		Weight per struck bushel pounds
		Grain bushels 32 pounds	Straw pounds	Grain bushels 32 pounds	Straw pounds	
1	Japan (Check)	57.1	2923	57.5	2517	30.0
2	Big Four	58.8	1874	59.3	1679	30.5
3	Czar of Russia	56.7	2818	57.3	2630	31.0
4	Sensation	59.3	2504	60.1	2439	30.5
5	Joanette	62.0	2123	63.0	2168	33.0
	Japan	56.5	2358			
6	Sixty Day	56.9	1991	58.3	2273	31.0
7	Siberian	58.6	3405	60.6	4174	30.0
	Japan	55.2	1900			
8	Swedish Select	60.9	2500	63.4	2967	29.0
9	Long's White Tartar ..	58.2	2830	60.6	3041	31.5
10	White Maine	59.7	2783	62.3	2734	30.0
	Japan	55.1	2783			
11	White Russian	58.8	2286	60.7	2026	31.0
12	Irish Victor	57.4	2710	58.6	2447	30.0
13	Heavy Weight Champion	54.5	2804	55.2	2587	30.0
	Japan	57.4	2710			
14	Fourth of July	56.9	1699	55.5	1715	30.5
15	Golden Fleece	55.6	2613	52.9	2746	30.5
16	Great American	58.4	2238	54.2	2518	31.0
	Japan	63.4	2079			
17	Golden Giant Side.....	49.3	2293	45.5	2544	30.5
18	Silver Mine	60.5	2900	56.8	2968	30.0
19	Liberty	56.3	2833	54.0	2904	31.0
	Japan	58.9	2839			
20	New Danish White	55.6	1690	54.9	1575	31.0
21	Probsteier	53.7	2622	53.6	2451	30.0
22	Lincoln	56.8	2874	57.3	2907	30.5
	Japan	56.3	2540			
23	Kherson	61.5	*	63.6	*	30.5
24	Mortgage Lifter	57.1	2513	59.7	2646	30.5

*An error was made in taking the total weight of Kherson, therefore the yield of straw per acre cannot be reported.

Test in 1910.

The oat varieties were treated for smut on March 28. One pint of formalin was used to 30 gallons of water, and the oats was immersed in the solution for 25 minutes.

The plat of ground on which the oat varieties were grown was plowed March 23, and 24. It was harrowed twice and rolled, and the oats were seeded April 14 and 15. The seeding was done at the rate of nine pecks per acre, with acid phosphate at the rate of 160 lbs. per acre. Each plat was 132.5 by 11 feet, and comprised .03346 acres.

The weather was very wet for two weeks after seeding, and the different varieties germinated very irregularly, causing a number of the plats to have a poor stand. During the growing season, the supply of moisture was quite good and well distributed, so that all of the varieties made a good growth of straw and a large yield of measured bushels. The weight per struck bushel was lower than for several preceding years. This may have been caused by exceedingly warm weather during the time of ripening.

The time of ripening was irregular, which may have been partly due to the irregularity of germination above referred to. Sixty Day and Kherson were cut July 19, while the remaining varieties were cut July 25, and 26, except Golden Fleece and Golden Giant Side, which were cut July 31, and August 1, respectively. All varieties were threshed on the same date.

As in the preceding year, the late variety, Golden Giant Side, made a comparatively low yield, which is also true of the other late variety, Golden Fleece, grown this year for the first time. The early maturing varieties, Kherson and Sixty Day, on the other hand, are among the high yielding varieties. The very low yields of Beardless Probsteier, Black Tartarian and Golden Rain are due to a very poor stand.

(For diseases for 1910 see Table of Description of Varieties.)

Yield of Varieties—1910.

No.	Variety	Actual Yields per Acre		Corrected Yields per Acre		Weight per struck bushel pounds
		Grain bushels 32 pounds	Straw pounds	Grain bushels 32 pounds	Straw pounds	
1	Japan (Check)	67.3	3006	67.8	2606	28.9
2	Big Four	64.8	2877	64.9	2539	28.2
3	Czar of Russia	71.8	3162	71.6	2840	28.2
	Japan	68.4	*1170			
4	Long's White Tartar	79.7	1890	79.6	1768	28.9
5	Fourth of July	71.7	2985	72.2	2836	26.5
	Japan	66.8	2691			
6	Golden Giant Side	58.0	4203	59.5	3772	28.2
7	New Danish White	59.0	2913	61.2	2435	26.5
	Japan	64.7	3330			
8	Joanette	66.0	3722	70.4	3143	26.9
9	Sixty Day	77.5	1929	87.6	1769	25.9
	Japan	57.6	2598			
10	Swedish Select	65.4	3396	74.8	3361	26.1
11	Kherson	69.3	2133	77.0	2084	26.9
	Japan	62.7	2703			
12	453-06	81.0	2598	83.8	2667	30.1
13	456-06	52.4	2523	52.1	2771	26.9
	Japan	70.7	2208			
14	456-06	70.7	2688	67.5	3049	26.9
15	473-06	77.2	2031	73.3	2217	30.1
	Japan	71.7	*1155			
16	585-06	76.0	1467	72.5	1488	28.8
17	White Maine	74.1	2790	71.4	2791	30.1
	Japan	69.8	2748			
18	Golden Fleece	58.4	1731	56.3	1730	26.6
19	Beardless Propsteier	26.2	2613	26.8	2766	25.6
	Japan	71.2	2313			
20	Regenerated Swedish Select	65.6	2520	63.0	2876	27.5
21	Welcome	58.4	2781	56.7	3217	24.5
	Japan	69.3	2223			
22	Clydesdale	82.7	2184	80.4	2474	30.1
23	Black Tartarian	21.0	4731	20.4	5108	24.3
	Japan	70.4	2457			
24	Canada Cluster	52.4	2643	50.4	2831	26.9
25	Golden Rain	25.8	2925	24.7	3164	32.0
	Japan	70.8	2385			

*Low yields of straw from Checks Nos. 2 and 8 indicate that an error was made in taking total weights of these plats. In taking total average of the weight of the straw from check plats, these weights were omitted.

Average Yield of Varieties.

It is a well known fact that the relative productiveness of varieties of any crop cannot be determined from a trial of only one year. For reasons not usually understood, the highest yielding variety in any one year may be a relatively low yielding variety the next, and so a fair trial of a variety should usually comprise tests for a number of years. For these reasons, two other tables are given. In the first is given the average yields of varieties tested for two years or more during the years 1906 to 1910, and in the next is given the average yield of each variety for all years tested. Japan, the variety longest grown at the Station, is used as the standard by which to compare all varieties.

Average Yields for Two to Five Years, 1906-1910, Compared with Japan.

	Number of Years	Yields per acre		Increase (or decrease) per acre as compared with Japan		Average weight per struck bushel pounds
		Grain bushels 32 lbs.	Straw pounds	Grain bushels 32 lbs.	Straw pounds	
Japan	5 yrs. 1906 to 1910	55.1	2639			31.6
Big Four		53.2	2309	—1.9	—339	32.8
Czar of Russia		53.3	2593	—1.8	— 46	32.2
White Maine		52.7	2563	—2.4	— 76	31.9
Long's White Tartar		54.6	2066	—0.5	—573	33.5
Fourth of July		54.1	2198	—1.0	—441	30.8
Golden Fleece		48.1	2127	—7.0	—512	32.0
Golden Giant Side		46.4	2526	—8.7	—113	31.4
New Danish White		51.3	2192	—3.8	—447	31.0
Japan	4 yrs. 1906 to 1909	51.9	2647			32.3
Sensation		47.0	2183	—4.9	—464	32.9
White Russian		45.9	2234	—6.0	—413	33.0
Irish Victor		49.4	2298	—2.5	—349	31.8
Heavy Weight Champion		48.6	2321	—3.3	—326	31.8
Great American		48.1	2829	—3.8	182	32.5
Silver Mine		48.8	2415	—3.0	—232	32.8
Liberty		47.6	2650	—4.3	3	31.5
Probsteier		48.0	2330	—3.9	—317	31.7
Lincoln		49.6	2665	—2.3	18	32.1
Mortgage Lifter		46.6	2260	—5.3	—387	33.2
Japan	4 yrs. 1907 to 1910	60.0	2857			31.0
Sixty Day		66.1	2131	6.1	—726	30.6
Swedish Select		59.7	2989	—2.3	132	32.3
Joanette		62.1	2769	2.1	— 88	32.3
Japan	3 yrs. '07-'09	57.4	2940			31.8
Siberian		55.3	3146	—1.1	206	33.3
Japan	2 yrs. '09-'10	62.7	2562			29.5
Kherson		70.3	2084	7.6	—478	28.7

Average Yields of All Varieties for All Years Grown Except 1896, Compared With Japan.

	Yield per Acre		Increase (or decrease) per acre over Japan		Weight per struck bushel lbs.
	Grain, bus. 32 lbs.	Straw lbs.	Grain, bus. 32 lbs.	Straw lbs.	
20 years, 1890-1910					
Japan	51.6	3064			34.1
14 years, 1895-1909					
Japan	52.8	3079			33.5
Lincoln	49.6	2948	—3.0	—131	32.3
12 years, 1898-1909					
Japan	52.8	3112			34.5
Liberty	52.9	3115	0.1	3	33.0
Sensation	49.7	2676	—3.1	—436	33.6
Mortgage Lifter	48.5	2842	—4.3	—270	35.2
11 years, 1899-1909					
Japan	53.0	3108			33.2
Heavy Weight Champion	53.0	2834	0.0	—274	32.2
Great American	50.7	2993	—2.3	—115	32.8
10 years, 1900-1909					
Japan	52.5	3034			33.3
Irish Victor	53.9	2755	1.4	—279	32.4
Silver Mine	53.9	2727	1.4	—307	32.9
9 years, 1901-1909					
Japan	54.5	2967			32.9
Probsteier	53.2	2761	—1.3	—206	32.3
7 years, 1903-1909					
Japan	55.4	3169			32.1
White Russian	52.2	2567	—3.2	—602	32.4
3 years, 1907-1909					
Japan	57.4	2940			31.8
Siberia	55.3	3146	—2.1	206	33.3
12 years, 1899-1910					
Japan	54.3	3066			32.8
White Maine	56.4	2874	2.1	—192	32.3
Fourth of July	55.7	2637	1.4	—429	31.1
10 years, 1901-1910					
Japan	55.8	3031			32.5
Golden Giant Side	53.1	3067	—2.7	36	31.4
Czar of Russia	56.8	2762	1.0	—269	33.3
New Danish White	55.1	2647	—0.7	—384	32.0
Big Four	56.0	2801	0.2	—231	33.1
Golden Fleece	51.3	2569	—4.5	—462	32.7
8 years, 1903-1910					
Japan	56.9	3099			31.6
Long's White Tartar	57.5	2481	0.6	—618	33.6
4 years, 1907-1910					
Japan	60.0	2857			31.1
Joanette	62.1	2744	2.1	—113	32.3
Sixty Day	66.1	2131	6.1	—726	30.6
Swedish Select	59.7	2989	—0.3	132	32.3

VARIETY DESCRIPTIONS

No.	VARIETY	Ht. Ft.	Culms; thick, medium, thin	Leaves; broad, medium, narrow	Head; side or panicled	GRAIN			DISEASES (1910)			Time of Ripening Early, medium, late
						Size; large, medium, small	Shape; long, medium, short	Color; white, yellow, black, brown	Rust; degrees in order	Blade-blight	Blast	
1	Japan (check)	3.7	Medium	Broad	Panicled	Large	Long	White	Some	Much	Much	Medium
2	Big Four	3.7	"	"	"	Large	Medium	White	"	Very much	Very much	"
3	Czar of Russia..........	3.7	"	"	"	Large	Long	White	"	" "	" "	"
4	Long's White Tartar	4.1	Thick	"	Side	Large	Short	White	"	" "	" "	"
5	Fourth of July	3.6	Medium	"	Panicled	Medium	Medium	White	"	" "	" "	"
6	Golden Giant Side	3.5	"	"	Side	Medium	Medium	White	"	" "	" "	Late
7	New Danish White	3.5		"	Panicled	Medium	Medium	White	"	" "	" "	Medium
8	Joanette	3.3	Thin	Medium	"	Medium	Short	Black	"	Much	Much	"
9	Sixty Day	3.3	"	"	"	Small	Medium	Yellow	Little	Some	Some	Early
10	Swedish Select	3.7	Medium	Broad	"	Large	Long	White	Some	Much	Much	Medium
11	Kherson	3.5	Thin	Medium	"	Small	Medium	Yellow	Little	Some	Some	Early
12	453-06	3.8	Medium	Broad	"	Large	Long	Black	Some	Much	"	Medium
13	456-06	3.5	"	"	"	Large	Short	White	"	"	Much	"
14	473-06	3.5	Thick	"	"	Large	Medium	White	"	"	Very much	"
15	585-06	3.5	"	"	"	Large	Medium	White	"	"	" "	"
16	White Maine	3.8	"	"	Side	Large	Short	White	"	"	" "	"
17	Golden Fleece	3.6	Medium	"	Panicled	Large	Long	White	"	"	" "	Late
18	Beardless Probsteier.....	3.8	"	Broad	"	Large	Medium	Yellow	"	Much	" "	Late
19	Regenerated Swedish Select	3.8	"	"	"	Large	Medium	White	"	"	Some	Medium
20	Welcome	4.0	Thick	"	Side	Large	Long	Brown	"	"	Very much	"
21	Clydesdale	4.0	"	"	"	Large	Long	White	"	"	" "	"
22	Black Tartarian	3.8	"	"	"	Small	Medium	Black	"	"	" "	Late
23	Canada Cluster	3.8	Medium	"	Panicled	Small	Short	White	"	"	" "	Medium
24	Golden Rain	3.8	"	"	"	Large	Short	Yellow	"	"	" "	Late

Resistance to Disease.

The oats grown in the variety testing grounds are treated for smut with formalin. The usual method of treatment is to immerse the oats for 25 minutes in a solution of one pint of 40 per cent. formalin to 30 gallons of water. After treating, the oats are spread out to dry. When treated in this way, no smut has been found on any varieties.

In 1908, the following varieties were sown on the College Farm in increase plats of about one acre each. (See table.) The seed for these plats was not treated for smut, and all showed more or less injury from smut when they were harvested. The percentage of heads destroyed by the disease was determined by counting 100 heads at each of three different places in each plat, then noting the number of smutted heads. and taking the average of the three for the result.

Variety	Percentage of Smutted Heads
Japan	11
Big Four	18
Czar of Russia	20
Long's White Tartar	10
Fourth of July	16
New Danish White	8
White Maine	10
Irish Victor	16
Average	13.6

Date of Ripening.

During the past five years, the date of ripening for oats on the Station farm (elevation 1200 feet) has ranged from July 12, to August 1. The time depends on variety, season and date of seeding. For the medium maturing varieties, the number of days from seeding to harvesting has ranged from 90 to 105; for the early maturing varieties, 84 to 96; and for the late varieties, during the past two years, 102 to 108. Late seeding generally results in a shorter season of growth than early seeding. In general, early seeding and early varieties are both desirable. Late varieties seldom produce as large yields as early or medium maturing varieties.

The Best Varieties.

Referring to the table giving average yields from 1906 to 1910 inclusive, we find in the group that have been tested for 5 years that none of the varieties have been equal to Japan, either in yield of grain or straw. Those most nearly approaching Japan in yield of grain are Long's White Tartar and Fourth of July. Of the next group, tested for four years, we find none that equal Japan in yield of grain and three that slightly exceed it in yield of straw. Those most nearly approaching Japan in yield of grain are Lincoln and Irish Victor. Of those tested for the four years, 1907-1910, inclusive, Sixty Day and Joanette have both outyielded Japan in grain, although they are below Japan in yield of straw. Sixty Day is a very early variety, with very short and light straw. As an average of the four years tested, it outclassed Japan by 6.1 bushels per acre, at the same time falling below Japan in average yield of straw to the amount of 726 pounds per acre. Japan gave two-thirds of a pound of grain for each pound of straw, while Sixty Day produced one pound of grain for each pound of straw.

Kherson, which has been tested for only two years, is also an early variety and closely resembles Sixty Day in both straw and grain. During the two years it outyielded Japan by 7.6 bushels per acre. During the same two years, Sixty Day outyielded Japan by 10.3 bushels per acre. These are two very promising varieties. Referring to tabulated description, we find that these two varieties are characterized by short, thin straw and small, medium long grains of yellow color. In 1910, they were less affected by rust, blade-blight and blast than any other varieties.

Of the medium maturing varieties, the following are recommended: Japan, Liberty, Heavy Weight Champion, Irish Victor, Silver Mine, White Maine, Fourth of July, Czar of Russia, Big Four and Joanette.

As a general proposition, late varieties are not recommended.

Winter Oats.

For three years, the Station has been conducting tests, in co-operation with farmers, in growing winter oats. Seed of winter oats has been sent to farmers in the counties of Bedford, Cambria, Chester, Delaware, Fayette, Green, Lancaster, Lebanon and York. With the exception of one report each, from the counties of York and Chester, the oats have failed to winter successfully.

The planting of 1908 at the Station all winter killed. That of 1909 gave about one-third of a crop. The results indicate that winter oats are not adapted to Pennsylvania conditions, although in mild winters they may succeed in the Southeastern portion of the state.

William ,ulleok

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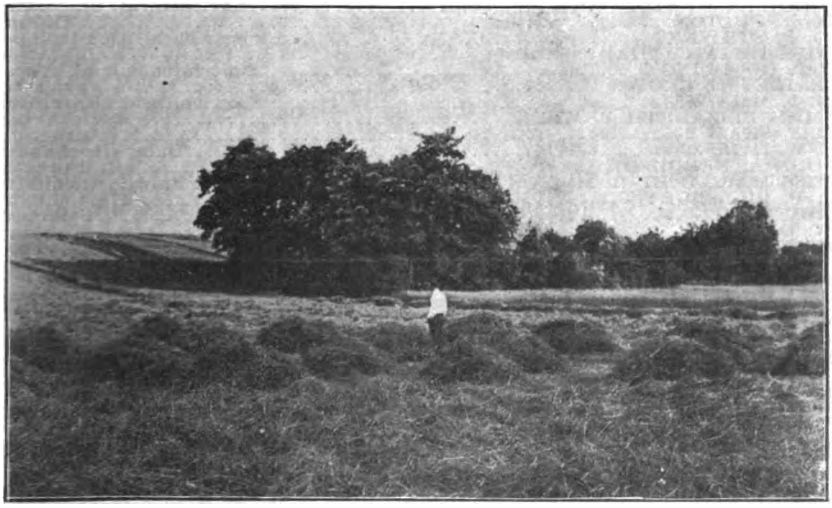
The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 109



SOME SOILING CROPS FOR PENNSYLVANIA

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
FEBRUARY, 1911

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AGRICULTURAL EXPERIMENT STATION
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* Absent on Leave.
† Assigned by the Bureau of Soils, U. S. Dept. of Agr.

The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 110

THE CONTROL OF INSECTS AND DISEASES AFFECTING HORTICULTURAL CROPS

H. R. FULTON W. J. WRIGHT. J. W. GREGG.

This bulletin is published to fulfill an urgent request from the growers of Pennsylvania for concise descriptions of and methods for controlling the principal insect enemies and fungous diseases of fruits and vegetables. Lack of space prevents a complete description, therefore special emphasis has been placed on control. It is well to remember that, for most fungous diseases and some insect enemies, spraying is a preventive rather than a remedy and, to be effective, must be done before the disease or insects are apparent and at the time when there is danger of attack; also that spraying is not a "cure-all," and that its efficiency may be greatly increased by sanitary methods of culture, etc.

It is practically impossible to acknowledge specifically the various sources of original publications drawn upon in the preparation of this bulletin; but, in some instances, where suggested remedies have not been verified by trials at this Station, the source of information is indicated.

The data relating to plant diseases and their control has been prepared by Professor Fulton; that on orchard insects and their control by Mr. Wright; and that on insects affecting vegetables and their control by Mr. Gregg.

INSECTICIDES.

Two general classes of materials are used in combating insect pests of plants:

1st: Internal poisons, which kill the insect when eaten with its food; and 2nd: external poisons which kill by acting from the outside, either by closing the breathing pores or by their caustic action upon the insect. The former are used to control insects which chew or eat some part of the plant. The latter are used mostly against sucking insects, which live upon the sap of plants.

Internal Poisons.

Most internal poisons contain arsenic in some form. For this reason they must be kept out of reach of children and animals. The most common are Paris green, London purple, lead arsenate and arsenite of lime.

Paris Green is a combination of arsenic and copper, which is insoluble in water, but when well made is so finely powdered that it may be mixed with water and applied as a spray if constantly agitated to keep it from settling. Ordinary commercial Paris green contains a small amount of soluble arsenic, which will burn the foliage. To reduce this, add freshly slaked lime equal in amount to the Paris green used. For apple, pear and other resistent plants, it may be used at the rate of 5 to 8 oz. to 50 gal. of water or fungicide. For peach and other stone fruits, its use is not advised. According to the National Insecticide Act of 1910, Paris green must contain not less than fifty per cent. of arsenious oxid and must not contain water-soluble forms of arsenic equivalent to more than three and one-half per cent. of arsenious oxid. Paris green is now being largely displaced by arsenate of lead.

London Purple is a combination of arsenic formed as a by-product in the manufacture of analine dyes. It contains more soluble arsenic than Paris green, and is somewhat variable in the percentage of combined arsenic. It is not recommended for general use but may be used with Bordeaux. Use a slightly smaller amount than of Paris green.

Arsenate of Lead contains less soluble arsenic than Paris green and is much less injurious to foliage. It also has the advantage of sticking like paint. It is supplied in two forms—as a powder and as a paste, both of which are white. For use, thoroughly mix the desired quantity with a small quantity of water and then strain into the barrel or tank. As a rule, from two to four pounds of paste or from 1 to 2 pounds of powder to 50 gallons of water or fungicide will be found entirely safe. In the following pages directions for using lead arsenate are made on the basis of the paste form. According to the National Insecticide Act of 1910, arsenate of lead must not contain more than 50% of water; must contain 12½% of arsenic oxid; and must not contain water-soluble arsenic in excess of three-fourths of one per cent. in terms of arsenic oxid.

Arsenite of Lime is one of the cheapest insecticides and may be easily made at home according to the following formula:

White Arsenic	2 lb.
Sal Soda (crystals)	2 lb.
Water	1 to 1½ gal.

Boil until dissolved and with this solution slake 3 or 4 pounds good stone lime. Add water to make two gallons. For use, add one quart of this solution to each 50 gallons of water.

Hellebore is a vegetable poison made from the roots of a plant. It is effective against most insects, but is less dangerous to man and the higher animals than arsenical poisons. Hence, it is used to control insects which appear near the ripening time of the fruit. It may be applied as a powder mixed with from 5 to 10 parts of flour or slaked lime, or in water at the rate of 1 oz, to the gallon. It is to some extent a contact poison, acting through the breathing pores of the insect. Its high cost precludes its general use. It deteriorates rapidly when exposed to the air and should be kept in tightly closed jars.

CONTACT POISONS.

Pyrethrum (often known as Buhac, Dalmatin, or Persian Insect Powder) is the powdered blossoms of a plant. It is not poisonous to man, but kills insects through their breathing pores. It is usually applied in the powder form full strength with a small bellows, or may be used as a spray at the rate of 1 oz. to 2 gallons of water. This should stand 24 hours before using. Pyrethrum loses its strength rapidly. It should be kept in closed packages and should be fresh when bought.

Tobacco Decoctions are useful in controlling plant lice (aphis) and other delicate insects. It may be made by steeping 1 pound of refuse tobacco in 2 gallons of water. Boil thoroughly and make the residue up to the original quantity of water. A number of satisfactory proprietary tobacco extracts are now to be found on the markets.

Kerosene Emulsion is a combination (emulsion) of kerosene and soap that will readily mix with and may therefore be diluted with water. It may be made with either hard or soft soap as follows:

Kerosene	2 gallons.
Soft Soap	1 qt., or hard soap ½ lb.
Water	1 gallon.

Dissolve the soap in water by boiling; then while hot, but after taking from the fire, add the kerosene. Agitate thoroughly by pumping through a force pump, directing the stream from the nozzle back into the vessel from which it was taken for 10 or 15 minutes or until it becomes of the consistency of cream and has increased one-third or more in volume. This stock solution contains about 66% of oil. For aphis and other insects, in summer, dilute to 6%. To find the amount of water necessary to add to make a spray of given percentage, divide the per cent. of oil in the stock solution by the per cent. desired. The result will give the number of dilutions. For example, to get a spray containing 6% of oil, divide 66 by 6,=11; that is, to one part stock solution, add 10 parts of water. At this Station the above method of making kerosene emulsion has been superceded by the cold method of making with a proprietary soap known as Tak-a-Nap soap. A pound of this soap is used to each gallon of oil and an equal amount of water added. This can be easily emulsified with the pump without heating, which is a great convenience. It may then be diluted to the desired strength.

Miscible or Soluble Oils are mineral oils which have been so treated that they may be readily mixed with water. There are several commercial brands on the market which are used with success by many orchardists in treating scale insects. They may also be made at home*. In using, care should be taken not to apply excessively, so that the oil will collect in crotches of the trees or on the ground about the trunk. They are, as a rule, more expensive than the lime sulphur sprays.

Storable Concentrated Lime-Sulphur†. This is a standard remedy for scale insects. Several commercial brands are on the market or it may be easily and cheaply made at home, according to the following formula:

Stone lime (at least 90% CaO)	50 lb.
Sulphur (flour, flowers or powdered commercial)	100 lb.
Water (to make when boiling is complete)	50-55 gal.

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* For directions for making, see Pa. Expt. Sta. Bul. No. 86.

† For complete discussion, see Pa. Expt. Sta. Bul. No. 99.

"Put 10 gallons of water in kettle and start fire. Place lime in kettle. After slaking is well started, add the dry sulphur and mix thoroughly, adding water enough to maintain a thin paste, which requires about five gallons. After the slaking and mixing are completed, add water to make about 50 gallons, bring to a boil, and stir until the sulphury scum practically disappears. Then add water (preferably, but not necessarily, hot) to about the 60-gallon height and boil again to 50 gallons, if storage space is limited. If it is not limited, a little more water may be added the third time and boiling stopped at about 55 gallons." "The time of boiling should be until the sulphur granules are dissolved. In general a period of 40 to 60 minutes of vigorous boiling is sufficient to put the sulphur into solution." When finished, it should be strained into closed vessels, or, if stored in open barrels, it should be protected from air by a layer of oil poured over the top. For use, it must be diluted to certain strengths noted below. This is indicated by a simple instrument, known as the "hydrometer," which sinks deeper in a weak mixture than a strong one. When made as above, the density will not be far from 1.24 as indicated by the hydrometer. As a spray for scale, a density of 1.03 has been found satisfactory. To find the number of dilutions necessary to secure this strength, divide the decimal (.24) of the reading of the stock solution by the decimal of the desired spray (.03). The result will be the number of dilutions, i. e., $.24 \div .03 = 8$. For use, add 7 gallons of water to one of the stock solution to make 8 gallons of spray of the required strength. Commercial brands usually have a sp. gr. of about 1.29.

Hydrocyanic Acid Gas. This is used for fumigating nursery stock and in greenhouses. *It is a deadly poison when inhaled and must be handled with caution.* For each 100 cu. ft. of space for dormant plants use

Potassium Cyanide (refined)	1 oz.
Water	3 oz.
Commercial Sulphuric Acid	2 oz.

Add the acid to the water in a glass or earthen vessel and into this drop the cyanide, at arm's length. Hasten from the room and close the door tightly. (The room should be one which may be tightly closed). Leave for 40 to 60 minutes and then open the doors and allow it to air out thoroughly before entering. For tender greenhouse plants, a much weaker gas should be used, about one-tenth as strong.

Whale Oil Soap. This is often used as a spray to control soft bodied insects, such as plant lice, etc. Use one pound of soap to from four to six gallons of water. Common laundry soap used at the same rate is often effective.

FUNGICIDES.

Bordeaux Mixture.

Copper Sulphate (Bluestone)	4 lb.
Lime (best grade stone lime)...........	4 lb.
Water	50 gallons

This is the 4-4-50 formula; a 3-4-50 mixture would have one pound less of bluestone. The bluestone may be conveniently dissolved in a few gallons of hot water, and made up to 25 gallons. Slake the lime to an even paste and add water to make 25 gallons. Mix these dilute solutions by pouring together slowly and churning constantly. Strain through a 20-mesh strainer, and use fresh. For small quantities it is convenient to keep a stock solution of bluestone made up one pound to the gallon, and to add lime solution to dilute portions of this stock solution, containing known quantities of bluestone. The lime may be slaked to a putty in quantity and kept under water in a barrel. When inconvenient to weigh the lime, a solution of potassium ferrocyanide, one ounce in a pint of water, may be used as a test solution to show when enough lime has been added. After each addition of a moderate trial quantity of dilute lime solution, let a few drops of the ferrocyanide fall on the surface; if these turn reddish brown, there is insufficient lime; if they remain clear yellow, enough lime has been added to combine with the copper. A slight excess of lime is desirable, and is obtained when equal weights of good stone lime and bluestone are used. A considerable excess of lime retards the fungicidal action, and does not seem to reduce injury as much as is commonly supposed. To avoid injury, reduce both bluestone and lime, and make an even and thorough application to secure the best protection with the weaker fungicide. Select a clear dry day. Arsenicals may be used in Bordeaux mixture.

Resin Sticker.

Boil together in the open two pounds of resin, one pound of sal soda crystals, and one gallon of water, until a clear brown color appears. Add this amount to 50 gallons of Bordeaux mixture for such plants as cabbage and asparagus, and to 100 gallons for other somewhat less waxy plants. It causes the fungicide to spread and adhere better on such plants, and prolongs the persistence of the coating.

Ammoniacal Copper Carbonate Solution.

Copper carbonate	5 oz.
Ammonia (strong commercial, 26° B.) about	3 pt.
Water	50 gal.

Make up the carbonate to a paste with a little water. Dilute the ammonia with eight times its volume of water and add to the carbonate paste. Use just enough ammonia to dissolve the carbonate and no more. Three pints will be about right for ammonia testing 26° Baumé. The solution will keep indefinitely, and may be diluted as needed. This is a clear fungicide of high efficiency, and is very useful on fruit approaching maturity and ornamental plants. It seems unsafe to use arsenicals with it unless lime is also added.

Neutral Copper Acetate Solution.

Dissolve one pound of neutral copper acetate in 50 gallons of water. It is a clear fungicide, the worth of which for late spraying of grapes has been demonstrated. It deserves more extended trial.

Potassium Sulphid Solution.

Dissolve one ounce of potassium sulphid (liver of sulphur) in three gallons of water, and use while fresh. It is a mild fungicide much used for powdery mildews of various sorts.

Flowers of Sulphur.

This is frequently used as a dust application, either pure or mixed with one or two volumes of air slaked lime. It is effective for superficial forms, like powdery mildews, and notably for asparagus rust and grape powdery mildew in the climate of California. It is most effective in a hot atmosphere, and where rains do not wash it off.

The fumes from heated sulphur are valuable in greenhouse fumigation. A paste is made by adding water to about equal parts of slaked lime and sulphur, and this is painted over the heating pipes. Fumes of burning sulphur are used for disinfecting empty greenhouses and storage cellars, but injure plants or fresh fruits or vegetables.

Self-Boiled Lime-Sulphur Mixture.

Sulphur (either flowers, or flour, or "commercial ground")	8 lb.
Lime (best grade stone lime)	8 lb.
Water	50 gal.

"The mixture can best be prepared in rather large quantities, enough for two hundred gallons at a time. The lime should be placed in a barrel and enough water poured on to almost cover it. As soon as the lime begins to slake the sulphur should be added, after first running it through a sieve to break up the lumps. The mixture should be constantly stirred and more water added as needed to form a thick paste at first and then gradually a thin paste. The lime will supply enough heat to boil the mixture several minutes. As soon as it is well slaked, water should be added to cool the mixture and prevent further cooking. It is then ready to be strained into the spray tank, diluted and applied. It is very important, especially with hot lime, to cool the mixture quickly by adding a few buckets of water as soon as the lumps of lime have slaked down. The intense heat, violent boiling, and constant stirring, result in a uniform mixture of finely divided sulphur and lime, with only a small percentage of the sulphur in solution." [Bul. 174, U. S. Bureau of Plant Industry]. In straining for use, the sulphur should be carefully worked through the strainer, the hard lime residue being discarded. A good agitator should be used in spraying. Arsenate of lead gives good results when added to this mixture.

Storable Concentrated Lime-Sulphur.

(See under Insecticides).

Bichlorid of Mercury Solution.

Dissolve one ounce of bichlorid of mercury (corrosive sublimate) in 7½ gallons of water; this is about a 1:1000 solution. The corrosive sublimate antiseptic tablets to be had at any drug store are convenient for making small quantities. It is useful as a general wound disinfectant, and for external disinfection of potato tubers, and seeds of various kinds. It is a deadly poison, and it corrodes metal vessels.

Formalin Solution.

Commercial formalin (40% formaldehyde)	1 pt. (or lb.)
Water	30 gal.

Be sure that the formalin is guaranteed full strength and is full measure. It deteriorates rapidly if not kept tightly stoppered. The strength indicated is for treating potato tubers. For oats smut or the stinking smut of wheat use 1 pint to 45 gallons of water. As a drench for disinfecting soil, use 1 pint to 15 gallons of water, and always allow a week or two for the formalin to evaporate thoroughly before planting in the soil.

Formaldehyde Gas.

Commercial formalin (40% formaldehyde)..	3 pt.
Potassium permanganate crystals	23 oz.

(Sufficient for 1,000 cu. ft. of space).

Have the enclosure practically air-tight. Put the formalin in an open dish of good size, add the permanganate, and retire quickly. Leave the place closed for 24 hours. This method is useful for disinfecting potatoes for scab on a large scale, and for protecting them and other root crops in storage. Its usefulness in fumigation will doubtless be greatly extended, although it is too strong for use with growing plants. It is expensive, but effective.

Steam Sterilization of Soil.

For effective sterilization, soil should be heated to 160° to 180° F. Burying potatoes at different depths and noting when they are cooked may be a guide. This will mean an exposure of a half hour or an hour, depending on the steam pressure and the means of applying. Sometimes a sterilizing bin is arranged with perforated steam pipes in tiers far enough apart for the dirt to be shoveled out. Another scheme is to use a harrow-like appliance, with perforated pipes that are forced into the soil. This has a flexible hose connection with the steam supply, and is moved successively to different parts of the beds. Probably the simplest arrangement is a shallow steam-tight box, some 6 to 10 feet in size, that can be inverted with the edges sunken in the loosened earth. Steam is supplied by hose, and the box is moved about. Sometimes permanent perforated pipes can be laid that may be used for sub-irrigating the growing crops, and for sterilizing the soil between crops. A boiling water drench has sometimes proved effective. Covering the treated soil with cloths to retain the heat longer will always be advantageous.

CONTROL MEASURES

(The principal insect pests and diseases are arranged alphabetically under each fruit and vegetable).

THE APPLE.

Aphids or Plant Lice.—In early spring, at or before blossoming time, there often appear on apple trees small green insects which live by sucking the sap from the leaves and young succulent growth. They are particularly injurious to the tender twigs of newly planted trees. On bearing trees they often attack the blossoms and young fruit, causing several fruits to set on a single spur, none of which develop properly.

Control: Spray with kerosene emulsion (6%) at their first appearance and before the leaves begin to curl. Spray forcibly and from beneath and be sure to hit every insect with the spray. Lime-sulphur at the density 1.04 applied just before the buds open is more or less effective.

Apple Maggot or Railroad Worm.—(*Rhagoletis pomonella*). Sweet and semi-acid apples are often found to be ruined by small brown tunnels extending indiscriminately through the flesh. This is the work of the Apple Maggot or Railroad Worm. It is the larva of a small fly which lays its eggs just underneath the skin of the fruit. When the apple falls to the ground, these larvae enter the ground, where they remain until spring, when they change into the adult fly.

Control: Since at no time in its life history does the insect eat any of the outside portion of the fruit or the foliage, spraying is of no avail. Fruit should be picked up and destroyed or fed to stock as soon as it falls and before the larva can escape to the ground. Pasturing the orchard will be found beneficial when practicable and through cultivation early in the spring will expose the wintering stage of the insects to birds.

Bitter Rot (*Glomerella rufomaculans*). This disease occurs infrequently in Pennsylvania. The brown rotten spots enlarge rapidly, and soon develop numerous minute pinkish pustules of spores. Cankers are formed on limbs where the fungus lives over winter, as well as in mummied fruit on the trees.

Control: Cut out and destroy all cankers; knock all fruit from the trees in the fall so it will rot thoroughly. Spray with 3-3-50 Bordeaux mixture two to four times, beginning six to nine weeks after blossoming, or immediately on the first appearance of bitter rot.

Black Rot or Canker (*Sphaeropsis malorum*). This fungus commonly causes fruit rot, limb canker and leaf spot. The rotten area enlarges rather slowly, is of dark color, and is covered with minute black dots that roughen it slightly.

Control: Give careful attention to the details of pruning, spraying and culture that characterize the best orchard practice. Coating the limbs and trunk with a winter fungicidal spray, or when the first scab application is made, and making an application to the leaves six weeks after blossoming, will sometimes be worth while, even when not required for other diseases.

Borers (*Chrysobothris femorata* and *Saperda candida*). There are two principal kinds of borers affecting the apple, the round-headed and the flat-headed. The former works in the trunk of the tree usually just above the surface of the ground. The latter may sometimes be found working in the larger branches as well as the trunk. Both are larvae of beetles. They bore through the bark and feed on the tissue just underneath the bark, often girdling and thus killing the trees. They do the greatest damage to young trees from the time of planting until they are 10 or 12 years old.

Control: The only effectual remedy is to dig them out with a sharp knife or kill them by pushing a soft wire into the burrow, which may be detected by the castings which the insect pushes out as it works. Careful search should be made each year in late summer or fall. Painting the trunk with *pure* white lead and oil without turpentine or dryer, for 18 inches above the ground is more or less effective in preventing the adult insect laying her eggs thereon. In some cases, the use of impure paints has been attended with some injury to the tree. In orchards where crown-rot is prevalent, care should be taken to disinfect the wounds carefully and also tools so that the disease may not be spread.

Bud Moth (*Tmetocera ocellana*). This insect, as is the case with most chewing insects, does its injury in the larva stage. The larvae feed on the buds just as they open, often causing serious injury. They are small, dirty white in color, and are not covered with hairs as are most leaf eating larva.

Control: Spray with arsenate of lead, 3 lbs. to 50 gallons of water just as buds open. If fungicide is not used at this time the arsenate of lead may be added to it at the same rate as to water.

Canker Worms (*Anisopterix pometaria* and *Paleacrita vernata*). There are two species of canker worms, the fall and the spring, which closely resemble each other and are controlled by the same sprays. Both are measuring worms which are the larvae of moths. They appear just before the blossoming time and feed upon the leaves, eating only that portion between the veins and leaving a brownish looking leaf skeleton. In some sections they become a serious pest and appear regularly every spring. The pupal stage is spent in the ground underneath the trees. The female moths are wingless and crawl up the trunk to lay their eggs on the twigs.

Control: (a) Spray a week or 10 days before blossoming time with 3 lbs. arsenate of lead to 50 gal. of water or fungicide. (b) Banding the trunks with sticky fly paper or some similar preparation keeps the female moth from climbing up to lay her eggs. It should be applied in the fall and again in early spring.

Cedar Rust (*Gymnosporangium spp.*). These fungi affect fruit, leaves and young shoots. They pass one stage of their life cycle on red cedars, causing "cedar-apples" or other stem deformity. Infection of apple always comes from the stage on cedars.

Control: Remove red cedars from the vicinity of an orchard, if possible. Spray susceptible apple varieties so as to to keep them protected while the "cedar-apples" are swelling in late spring.

Codling Moth or Apple Worm (*Carpocapsa pomonella*). This well known insect probably does more damage to the apple crop than any other. Its injury, however, is confined almost wholly to the fruit and as it does little or no injury to the tree it is often considered of less importance than some other insects. As the method of control depends upon a knowledge of its life history, it is briefly given.

The "worm" is the larva of a small moth which appears about ten days after the petals fall and soon after lays its eggs upon the new leaves. In about ten days these hatch and the larvae begin to search for the young fruit. Ninety per cent. enter the young fruit through the calyx or blossom end. They bore to the center of the apple where they feed upon the core. Here they remain until full grown (about 26 days) and then cut their way out, crawl under a convenient bark scale, and in about 20 days emerge again as adult moths which soon begin laying eggs for the second brood. This second brood appears about nine weeks after the petals fall.

Control: (1) Spray with arsenate of lead, 2 to 3 pounds to 50 gallons of water*, when about 80% of the petals have fallen, and complete the spraying within eight days (use a nozzle throwing a coarse spray). Spray with plenty of pressure (125 to 150 lb.)** and direct the material into the throat of every blossom. The object of this first spraying is to place a quantity of the poison in each calyx cup to be eaten by the young larva when it attempts to enter.

(2) Follow the first spraying in 10 days or two weeks with a similar spray, but put it on as a fine mist which will cover every leaf and fruit. This is at the maximum hatching period and is designed to poison those larvae which try to eat through the side of the apple or which feed upon the leaves while searching for the young apples.

(3) Duplicate No. 2 about nine weeks from the date of the first.

Collar Rot. (Cause unknown). In the absence of definite knowledge regarding causation, it is suggested that corrosive sublimate disinfectant be used on all wounds and tools in borer removal, and that affected bark be cut out as thoroughly as possible and the exposed parts disinfected and painted with tar or pure lead paint. To promote their recovery, fertilize affected trees, and cultivate to conserve moisture, trim to reduce leafage and prevent fruit-bearing for a few seasons.

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* When a fungicide is used the poison may be added to it at the same rate as to water.

** If Bordeaux is used as a fungicide it is quite liable to cause russeting of the fruit when applied at this pressure, and a separate spraying is desirable. If lime-sulphur is used, the danger of russeting is slight.

Crown-Gall. (See under Raspberry).

Curculio (*Anthonomus quadrigibbus*). This is a small brownish insect about $^3/_{16}$ of an inch long with a snout nearly as long as its body and four humps on the rear part of its back. It does its injury in two ways: (1)—by drilling small holes (feeding punctures) in the apple, around which decay starts, and (2)—by laying eggs in similar punctures which develop into small larvae or grubs which eat their way into the fruit. Fruits attacked are usually deformed and unfit for market.

Control: This insect attacks the fruit soon after it is formed. It may be controlled by coating the surface of the young apple with some arsenical poison, which will be eaten by the insect when making the puncture. Thorough spraying for codling moth (which see) is usually effective. If, however, the presence of curculio is suspected, the amount of poison in the first codling moth spray may well be increased to four pounds arsenate of lead to 50 gallons. The plum curculio (see under Plum) also attacks the apple, often doing more damage than the apple curculio.

Fall Web Worm (*Hyphantria cunea*). In late summer and during the autumn large webs or nests are often seen enclosing a part of a branch and in which black and yellow caterpillars may be seen eating the foliage. This insect always feeds inside the web where it is impossible to penetrate with either arsenical or contact sprays.

Control: The most efficient method is to burn out the nests with a torch made of old cloths fastened on a long pole and soaked in kerosene. Hold far enough below the nest to cook the caterpillars without burning the web so quickly that they will then fall uninjured to the branches below. If an infestation is expected spray with lead arsenate 3 lb. to 50 gal. of water just before the time of their usual appearance or when the first webs appear.

Fruit-Spot (*Cylindrosporium pomi*). It has been shown recently that this common disfigurement of Baldwin and other varieties is a fungous trouble, and that it can be satisfactorily controlled by spraying twice with weak Bordeaux mixture or lime-sulphur about July first and fifteenth. It must not be confused with fruit-pit, a different trouble, for which no successful method of control is known.

Leaf Miners. This name is given to several species of minute insects which work between the upper and lower surfaces of the leaves and when numerous may cause serious injury.

Control: Spraying is of little direct value, though some growers report this insect less troublesome in well sprayed than in unsprayed orchards. The insect passes the winter in the fallen leaves and destroying these by burning will control it.

Oyster Shell Scale (*Mytilaspis pomorum*). This is a comparatively harmless scale found in most all apple and pear orchards but it sometimes becomes so numerous as to be a serious pest. Full size specimens are a little more than an eighth of an inch long, are brownish in color and resemble somewhat a miniature oyster shell, whence its name.

Control: This insect passes the winter in the egg stage and is difficult to control by spraying during the dormant season. It is best controlled by spraying with dilute lime-sulphur (sp. gr. 1.01) or kerosene emulsion 6%.at hatching time, which at State College usually occurs about the first of June.

Scab (*Venturia inaequalis*). The fungus attacks fruit, fruit spurs and leaves. It is carried over winter on the last. Spores from these are scattered while the leaves and fruit are forming.

Control: Protection can be secured by spraying three times with 3-3-50 Bordeaux mixture, or concentrated lime-sulphur diluted 1½ to 50 (sp. gr. 1.01). Make the first application just before the blossoms open; the second just after the petals fall; and the third two weeks later. Some resistant varieties need not be sprayed for scab; others slightly susceptible may have the first application omitted. In badly infected orchards, it is well to make a cleansing application to limbs before the leaf buds open. Seasonal conditions greatly influence the severity. Sometimes in cool, moist seasons a summer application, nine weeks after the petals fall, will be needed to prevent late infection.

San José Scale (*Aspidiotus perniciosus*). This most serious of scale insects attacks practically all fruit trees and many forest and shade trees. It is a minute insect which soon after birth finds a convenient spot, inserts its proboscis through the bark and begins the formation of a scale on its back. This scale is roundish in form, rarely more than 1/16 inch in diameter and is distinguished by a raised point in the center which is surrounded by a slightly depressing ring.

It attacks both tree and fruit. On the twigs the scales may become so numerous as to form a scurfy incrustation of a brownish gray color. If the infested bark be removed a red discoloration will be noticed. On the fruit each scale is surrounded by a conspicuous red blotch. This makes its appearance easily detected on bearing trees.

Control: Contact poisons alone are effective, of which both lime-sulphur at a density of 1.03 and miscible oils about 1 to 15 when thoroughly applied during the dormant season are successful. In spraying, care should be taken to cover every part of the tree because of the rapidity with which it multiplies. Experiments at this Station during the summer of 1910 show that it is possible to control this pest by spraying with dilute lime-sulphur during the summer when applied frequently. Three applications at a density of 1.01, applied immediately after the young began to emerge and at intervals of 10 days thereafter completely controlled a bad infestation on the apple.

Scurfy Scale (*Chionaspis furfurus*). This insect is white or grayish in color, is easily seen and varies in form from triangular (females) to narrow rectangular (males). In life history, size and treatment, it is much the same as Oyster Shell Scale described above.

Sooty Blotch and **Fly-Speck** (*Leptothyrium pomi*). The fungus is on the surface of the fruit, and is easily prevented by the ordinary scab applications, with possibly the summer one if moist conditions prevail. Prune to admit light and air.

Tent Caterpillar (*Clisiocampa americana*). This insect is often confused with the fall web worm, described above because of its custom of building a web or nest in the branches. It appears much earlier in the season, however, and the caterpillars are larger and brighter in color. These caterpillars differ also in that they go outside the nest to feed and return only at night or in bad weather.

Control: Burn out at night as for Fall Web Worm or spray with a strong arsenical spray as soon as they make their appearance.

Twig-Blight and **Blight-Canker** (*Bacillus amylovorus*). This is the same bacterium that attacks pear and quince. Blossoms and forming fruit may be attacked as well as leafy twigs and the bark of larger limbs. For treatment see fire-blight of pear.

Tussock Moth (*Notolophus leucostigma*). The larva of this moth is a leaf eating caterpillar a little over an inch long when full grown. They are yellow in color with a red head and a tuft of long hairs projecting from the front and two from the rear part of the body. It also has four cream colored tufts along its back from which it gets its name. Its injury is not confined to the apple for it works on many shade and forest trees.

Control: Pick off the large egg masses which appear as a frothy mass on the trunks of trees during the winter and spray as soon as caterpillars appear with an arsenical.

Woolly Aphis (*Schizoneura lanigera*). This is a small brownish insect much resembling in form and shape the aphis described above except that when found on the branches it is covered with a white wool-like substance. On the roots where it does its greatest damage the wooly covering is not present. It sucks the sap and large gall-like swellings appear on the roots where it attacks them.

Control: Young trees affected with this insect should not be planted. It may be controlled on the branches by spraying with kerosene emulsion 10% or tobacco extracts. When present on the roots, remove the soil from about the roots to a depth of four inches, place in the bottom a layer of refuse tobacco and replace the soil. The leaching from the tobacco is more or less effective in killing and driving them away.

GENERAL SPRAYING TREATMENT FOR APPLES.

(1) Lime-sulphur sp. gr. 1.03 or miscible oils 1 to 10. Apply in winter or early spring before buds start.

(2) Lime-sulphur sp. gr. 1.01 or Bordeaux 3-3-50. just before blossoms open. If canker worm or bud moth is present add arsenate of lead 2 pounds to 50 gallons.

(3) Same as No. 2 with addition of arsenate of lead 2 pounds to 50 gallons for apple scab and codling moth. Apply within 8 days after petals fall.

(4) Repeat No. 3 ten days later for apple scab and codling moth.

(5, 6 & 7) Bordeaux, 3-3-50, at intervals of two or three weeks beginning 8 or 9 weeks after petals fall. For bitter rot, fruit-spot and leaf-spot. Add arsenate of lead 2 pounds to 50 gallons in No. 5 for second brood of codling moth, if necessary, and to 6 and 7 for leaf eating insects if present.

ASPARAGUS.

Asparagus Beetle (*Crioceris asparagi*). There are two closely related species that feed on the tender shoots as well as on the mature stalks.

Control: Leave some plants uncut as traps. Dust plants with air-slaked lime, allow chickens to run over the field during the cutting season, and after the cutting season spray with lead arsenate, 2 lb. to 50 gal. of water.

Asparagus Miner (*Agromyza simplex*). The maggot mines under the skin of the young shoots at their base or below the surface.

Control: Leave trap plants to be pulled and burned after the fly has deposited her eggs.

Rust (*Puccinia asparagi*). Numerous small brown or black spots appear on the stems in midsummer or later, and the tops yellow prematurely.

Control: Do not allow any plants to mature during the cutting season, and destroy volunteer asparagus in the vicinity. Cut and burn affected tops in the fall. Practice the best methods of fertilization and cultivation. Propagate from resistant individuals. Some varieties, as Palmetto, are more resistant than others. Spraying throughout the season with resin Bordeaux or commercial lime-sulphur, beginning when the shoots are one or two feet high, has sometimes given satisfactory results.

BEAN.

Anthracnose or Pod-Spot (*Colletotrichum lindemuthianum*). Dark sunken spots develop on the pods, stems and leaf-veins. The fungus threads penetrate the seed in spotted pods, and on germination infect the seedling leaves, later spreading to the forming pods.

Control: Avoid planting seed from any but perfectly clean pods. If this is impossible, spray very thoroughly with 5-5-50 Bordeaux mixture just after the plants have broken through the ground; again when the first leaves have expanded; and a third time soon after the blossoms have fallen. Do not work the plants while wet, and so avoid spreading the spores.

Bacterial Blight (*Bacterium phaseoli*). The spots on the pods appear water-soaked, and are not sunken. Large areas in the leaves become watery, then yellowish, and gradually die. Like the pod spot this disease gets its start from planting infected seed.

Control: Plant seed from clean pods only. Thorough spraying helps in the control, probably by keeping away insects that transfer the bacteria.

Bean Weevil (*Bruchus obtectus*). A most formidable enemy attacking the pods of growing plants and breeding in stored seeds in successive generations.

Control: Treat seed immediately after harvesting by fumigating for twenty-four hours with carbon bisulphide, 1 teaspoonful to 1 cubic foot of box space.

Variegated Cutworm (*Peridroma saucia*). The most destructive and widely known of all cut worms attacking garden plants, cutting the young bean plants off at the surface of the ground.

Control: Poison baits are most successful. Spray a patch of clover with Paris green or arsenate of lead and sprinkle the clover along the rows of cultivated plants. Bran mash bait, made of molasses, bran, Paris green or white arsenic mixed to a paste and placed along the rows, is still an efficacious remedy.

BEET.

Blister Beetle (*Epicauta marginata*). The blister beetles are the most common of all beet enemies, often defoliating whole fields.

Control: Spray with Paris green, 1 lb. to 150 gal. of water; or arsenate of lead, 2 lb. to 50 gal, of water.

BLACKBERRY.

(See Raspberry).

CABBAGE AND CAULIFLOWER.

Black Rot (*Bacterium campestre*). This disease may be recognized by the dark discoloration of the veins or fibres of the leaves and stems. Black rot bacteria that may adhere to cabbage seed are a source of danger.

Control: Disinfect the seed by soaking for fifteen minutes in 1 to 1000 corrosive sublimate solution. Use clean soil for the seed bed. All cabbage refuse should be removed from infested fields and destroyed, and cabbage or related plants prevented from growing there for several years. If the disease appears, control insects that may spread the bacteria, and destroy badly affected plants.

Cabbage Worm (*Pontia rapae*). The common white butterflies seen in cabbage fields lay eggs that hatch into velvety green worms that feed on the leaves.

Control: Before heads form, spray with Paris green, 1 lb. to 150 gal. water; arsenate of lead, 2 lb. to 50 gal. water; after heads begin to form spray with hellebore, 1 oz. to 1 gal. of water.

Cabbage Aphis (*Aphis brassicae*). Very troublesome in some seasons, but may be controlled by spraying with nicotine preparations either in solution or as a dust; and before the plants begin to head spray with kerosene emulsion, 1 to 6, (about 10%) or whale oil soap at same strength.

Cabbage Maggot (*Pegomya brassicae*). A small fly lays eggs near the plants and the white maggots bore into the center of the roots.

Control: Pour carbolic acid emulsion or carbon bisulphid around plants, 1 tablespoonful to a plant. Dip roots of young plants before setting in arsenate of lead and water. Clear field of cabbage stumps and fall plow. Tarred paper cards may be used on a small scale.

Club-Root or **Big Root** (*Plasmodiophora brassicae*). This organism lives over in the soil. The same care in securing sound seedling plants, in rotating crops and in destroying infected trash should be practiced here as for black rot. Guard against carrying infected soil or manure to uninfected spots. Liming the soil heavily in the fall will sometimes check the disease, but apparently not under all conditions. Insects do not spread this disease.

Cut Worm. (See Bean).

Damping-Off. This trouble is caused by several soil inhabiting fungi. It usually develops among seedling plants when they are crowded or too moist.

Control: Steam soil that is to be used for the seed bed, or drench with formalin solution. The trouble may be checked by thinning the plants, securing good ventilation and lighting, and maintaining a minimum of warmth and moisture. Keep the surface soil broken, so as to dry readily, or add a layer of clean dry sand. Sulphur may be dusted over the surface.

Harlequin Cabbage Bug (*Murgantia histrionica*). A bright colored bug appearing in large numbers and sucking the sap from the leaves. Hard to control. Practice clean cultivation, fall plowing, or use trap crops like mustard, radish or rape planted early. Spray trap crops with kerosene or pull and burn.

CARROT.

(See Parsnip).

CELERY.

Celery Caterpillar (*Papilio polyxenes*). One of the best known enemies of celery, but seldom appears in large enough numbers to cause much damage. Hand picking is the best way of destroying them.

Celery Leaf-Tyer (*Phlyctaenia ferrugalis*). A troublesome insect in certain celery sections, feeding on the under side of the terminal leaves.

Control: Spraying with Paris green or arsenate of lead before the stalks get large will help to control the larvae.

Celery Looper (*Plusia simplex, Guen*). A very destructive insect in some sections and may be controlled by the same methods used for the cabbage worms (See cabbage).

Early Leaf-Blight (*Cercospora apii*). Plants may develop this disease in the seed bed, and it is most prevalent in early summer.

Control: Keep young plants coated with 4-4-50 Bordeaux mixture, later using the non-staining ammoniacal copper carbonate solution. Well-drained, half-shaded fields seem to suffer less than others.

Heart-Rot. This trouble seems to be of bacterial origin. It would seem advisable to destroy affected material, store carefully, rotate crops, and disinfect seed.

Leaf-Spot (*Septoria petroselini*). This disease affects celery stalks as well as leaves, and causes rot in storage. Affected areas are dotted with minute black specks, which distinguish it from early blight. Spray the plants thoroughly as a preventive. Avoid introducing diseased material into storage; and give careful attention to the ventilation, moisture and temperature of storage places.

CHERRY.

Aphids or Plant Lice. (See under Apple).
Black Knot. (See under Plum).
Borers. (See under Peach).
Brown Rot. (See under Peach).
Bud Moth. (See under Apple).
Cherry Slug. (See under Pear).
Curculio. (See under Plum).
Fruit Bark Beetle. (See under Peach).
San José Scale. (See under Apple).

Shot-Hole or **Leaf-Blight** (*Cylindrosporium padi*). The leaves become brown spotted or small areas drop out leaving holes. They fall prematurely causing loss in the immediate crop, or a failure to mature wood growth properly.

Control: Spray the trees two or three times with Bordeaux mixture, or 8-8-50 self-boiled lime-sulphur, or 1¼-50, (sp. gr. 1.007) lime-sulphur solution, with intervals of two weeks, beginning as soon as the disease appears.

CHESTNUT.

Bark Disease or Blight (*Diaporthe parasitica*). The inner bark of large and small limbs is destroyed by a fungus that enters through wounds.

Control: Cut out and destroy affected parts as soon as they are seen. Disinfect all wounds made and tools used with corrosive sublimate solution. Keep close watch for the first appearance of the trouble, since it is very difficult to control after becoming established. Be sure that young trees come from uninfected nurseries.

Chestnut Weevils (*Balaninus proboscideus* and *Balaninus rectus*). Two species of weevils attack the chestnut. They are of the class known as snout beetles, resembling the curculio of apple, peach and plum but are much larger in size. Just before the nuts ripen these insects drill holes through the burr and deposit their eggs in the nuts. From these eggs hatch the familiar chestnut worms or larvae.

Control: Spraying is of little avail. Since the insects live in the orchard over winter, clean culture or at least the removal of all rubbish assist in control. Pick up all nuts as soon as they drop and fumigate with bi-sulphide of carbon in order to kill the young weevils which are in the nuts. Place the nuts in a tight box and use one ounce of the carbon bisulphide to a bushel of nuts and allow to remain from 16 to 20 hours.

CUCUMBER.

Anthracnose (*Colletotrichum lagenarium*). Rather definitely outlined brown spots occur on leaves and stems, and water-soaked sunken spots on the fruit.

Control: Spray with 3-4-50 Bordeaux mixture every two weeks after the vines begin to run.

Bacterial Wilt (*Bacillus tracheiphilus*). Scattered plants wilt gradually without evidence of injury to stem or roots. The sap tubes are filled with a milky, stringy mass of bacteria instead of the watery sap. Various insects spread the bacteria in their feeding.

Control: Keeping the plants covered with 3-4-50 Bordeaux mixture will make them distasteful to such insects, and so lessen the spread. Cut out and destroy affected parts promptly, and practice rotation of crops.

Downy Mildew (*Pseudoperonospora cubensis*). The leaves become yellow and die without wilting; and on the under side there is a downy fungous growth with dark metallic luster. It develops late in summer, but spreads rapidly.

Control: Continue the use of Bordeaux mixture, substituting ammoniacal copper carbonate to avoid staining the fruit. Try to spray the under side of the leaves thoroughly. In greenhouses maintain proper ventilation, heat and moisture.

Striped Beetle (*Diabrotica vittata*). A very destructive yellow beetle with black stripes attacking young plants.

Control: They may be controlled by dusting young plants with lime, soot, tobacco dust, Paris green or powdered arsenate of lead, alone or in combination. Spraying with Bordeaux mixture, 3-4-50 with 2½ lb. arsenate of lead, or using extra plants as traps and by covering hills with netting until the plants begin to vine. Plant an excess of seed and keep plants growing vigorously.

The Pickle Worm. (See Melon).

CURRANT.

Anthracnose (*Pseudopeziza ribis*). The fungus causes one type of leaf-spot; it also affects stems, fruit-stalks and berries, causing shedding of the last.

Control: Spray three times with 4-4-50 Bordeaux mixture; first, before the leaf buds open; second, as the leaves take form; third, two weeks later. Besides the anthracnose fungus, two others cause spotting of currant or gooseberry leaves. When serious, they are to be controlled in the same way.

Imported Currant Worm (*hematus ribesii*). This well known insect hardly requires description as it is almost sure to appear wherever currants are planted. Because of the large numbers and their voracious appetites they often entirely defoliate the plants before they are observed.

Control: Watch closely for the first appearance and then apply hellebore either in the powdered form or dissolved in water at the rate of one ounce to two gallons. Repeat as worms continue to hatch. On a large commercial scale, arsenate of lead is often used successfully by applying just before worms usually appear, paying special attention to the lower branches.

EGGPLANT.

Aphis. (See Melon).
Cutworm. (See Bean).

Eggplant Flea Beetle (*Epitrix fuscula*). Considerably larger than the potato flea beetle and punctures small holes in the leaves for the purpose of feeding.

Control: They may be controlled by spraying with Paris green or arsenate of lead in Bordeaux mixture. Young plants at transplanting may be dipped in an arsenate of lead-Bordeaux solution. Kerosene emulsion and the soap washes are often successful.

The Potato Beetle. (See Potato).

GRAPE.

Black Rot (*Guignardia bidwellii*). Brown spots dotted with minute black specks occur on leaves and stems. Affected berries rot and shrivel. The fungus passes the winter on infected plant remains.

Control: Burn all trash, or thoroughly cover it by plowing before new growth begins. Prune and train vines to admit light and air. Keep down weeds and avoid moist situations. Moisture for two or three days is necessary for infection by this fungus. Spray with 4-4-50 Bordeaux mixture, applying in so far as possible just before wet periods. Begin when the shoots are eight inches long and make five or six applications in all. For the late applications use ammoniacal copper carbonate, or neutral copper acetate.

Downy Mildew (*Plasmopara viticola*). Leaves and fruit are attacked. On the former large areas turn yellow and then brown, with a downy white growth on the under side.

Control: Spraying as for black rot will control.

Flea Beetle (*Haltica chalybea*). This is a small, steel-blue beetle which appears in vineyards in early spring. It feeds upon the foliage and also lays its eggs upon the leaves from which hatch small larvae which riddle the leaves with holes.

Control: Spray just as buds open with lead arsenate, 3 lb. to 50 gal., repeating with a similar or more dilute spray in about 2 weeks. Clean culture is essential as the insect winters in rubbish about the vineyard.

Grape Root Worm (*Fidia Viticida*). This is without doubt the most serious insect pest of the grape in this (Pennsylvania) grape belt. It works on the roots, seriously injuring the vines and in time kills them. The adult is a beetle which for a short time feeds on the leaves which affords a method of control.

Control: Spray with arsenate of lead, 3 lb. to 50 gal. of water or Bordeaux as soon as beetles make their appearance which in the Erie

County grape belt is normally between June 20 and 25. Follow this with a second application a weeek or 10 days later.* The following control method is also effective in destroying the pupae which are found just underneath the surface of the ground under the vines: At the last cultivation in the fall a broad ridge of earth is thrown up underneath the vines. The pupal cells are made in this and the following spring when the soil is leveled by cultivating the cells are exposed and picked up by birds.

Powdery Mildew (*Uncinula necator*). The fungus forms thin cobwebby patches on the upper surface of leaves without killing them. Affected berries are hard, brown and rough, and often crack.

Control: Spraying as for black rot will control.

Rose Chafer (*Macrodactylus subspinosus*). A well known enemy of the rose which often attacks the grape, eating the leaves, blossoms and young shoots.

Control: This is one of the most difficult insects to control by spraying. Contact poisons diluted so as not to injure the foliage have little effect and arsenical poisons are slow acting. Best results on a commercial scale have been secured with arsenate of lead, 4 to 5 lb. to 50 gal., applied just after leaves appear.

KALE AND KOHLRABI.

The same insects attacking cabbage will attack kale and kohlrabi. (See Cabbage for insects and remedies).

LETTUCE.

Aphis. (See Melon).

Downy Mildew (*Bremia lactucae*). There is a yellowing in indefinite leaf areas, and a delicate downy growth on the under side. Avoid too high temperature and excessive moisture. Ventilate well. Remove affected leaves promptly.

Drop (*Sclerotinia libertiana*). Affected plants collapse suddenly, and decaying parts are soon invested with a dense white moldy growth in which develop small black bodies that have white centers and become hard on drying. These bodies propagate the fungus later.

Control: Diseased plants should be systematically destroyed to prevent their formation. If this is not done, soil sterilization by steam, or change to clean soil must be resorted to. Satisfactory control can be secured by having only the upper one or two inches of soil sterilized. Avoidance of surface watering, and maintaining proper ventilation and a low night temperature are important.

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*U. S. Bureau of Entomology Bul. No. 89.

Leaf-Rot (*Botrytis vulgaris*). Rotted parts are covered with an ash-colored, downy growth. Perfectly vigorous plants are seldom attacked. High temperature at night or on cloudy days, poor ventilation and excessive moisture favor this rot. If the older leaves are attacked, a proper amount of food for growth cannot be supplied, and the younger ones remain half developed, giving a rosette type of growth. Destroy infected trash.

Root-Disease (*Rhizoctonia sp.*). This soil fungus may cause damping-off of seedling plants, or rot of stem or roots of older plants. From interference with root activity, the plants may assume the rosette habit; but this habit is not a necessary accompaniment of *Rhizoctonia* attack, and it may be produced by other causes. *Rhizoctonia* attacks most severely plants that have been checked in development, or are otherwise in weak condition.

Control: Maintain at all times proper conditions for the best growth of the crop. Sterilize infested soil by steaming, or formalin drench; or substitute clean soil. Give special care to the seed bed, and to the plants just after transplanting.

Tip-Burn. This is due to the breaking down and dying of tissue that was not well formed, or that could not be maintained under changed conditions of growth. Too rapid growth resulting from high temperature at night and on dull days, is the most frequent cause.

MELON.

Anthracnose, Bacterial Wilt, and **Downy Mildew.** (See under Cucumber).

Aphis (*Aphis gossypii*). The most typical of all plant lice attacking various other crops besides the melon. They are sucking insects and may be killed by spraying with a 10% solution of kerosene emulsion or soap solutions at the rate of 6 lb. whale oil soap to 50 gal. of water. Dusting with tobacco dust is a common remedy. Soaking sawdust or sand with bisulphid of carbon or kerosene and sprinkling under and around the vines is a good repellant.

Leaf-Blight (*Alternaria brassicae*). There are small brown spots that enlarge and run together. They show target-like markings, and the dead tissue is apt to break from the centers. Leaves die, and the fruit ripens prematurely and is of poor quality. Satisfactory control results from thorough spraying as for anthracnose. Resistant strains have been developed.

Melon Caterpillar (*Diaphamia hyalinata*). (Remedies same as for Pickle Worm).

Pickle Worm (*Diaphania nitidalis*). A caterpillar that feeds in its earlier stage in the buds or leaves and later by boring cavities in the rind of many cucurbits.

Control: The pickle worm has not been successfully combated. Arsenate of lead at the rate of 2 lb. to 50 gal. of water sprayed thoroughly during the early stages of growth will kill many. Methods used to control striped beetle may help to check the pickle worm. (See Cucumber).

Potato Flea Beetle. (See Potato).

Striped Cucumber Beetle. (See Cucumber).

ONION.

Damping-Off (See under Cabbage).

Downy Mildew or **Blight** (*Peronospora schleideniana*). Affected leaves are covered with a violet-tinted furry growth of the fungus; they become pale and collapse in a few days.

Control: Spray with 5-5-50 Bordeaux mixture with resin sticker, beginning when the plants have three leaves, and continuing throughout the season.

Imported Onion Maggot (*Pegomya cepetorum*). For control see Cabbage.

Onion Cut Worm (*Euxoa messoria*). For remedies see Bean.

Onion Thrips (*Thrips tobaci*). Exceedingly minute insects that both suck and chew, causing wilting of affected parts.

Control: Spraying early with contact solutions like kerosene emulsion, 1 to 6, (about 10%) or whale oil soap at the same strength. Plants may be dipped in such solutions at the time of transplanting in the field.

Smut (*Urocystis cepulae*). Dark dusty streaks occur on leaves and bulb scales. The fungus persists in the soil, and infection is from this source, and can affect sprouting seeds only. Transplants or sets, if grown on clean soil originally, will not afterwards contract the disease. Dry sulphur or formalin solution may be applied in the drill rows at the time of planting, if onions are to be grown from seed in infested soil.

PARSNIP.

Insects that attack celery may also trouble the parsnip and carrot. (See Celery).

Carrot Beetle (*Ligyrus gibbosus*). The worst insect enemy of the parsnip and carrot.

Control: Remedies are few and unsatisfactory. Apply lime, practice crop rotation and allow chickens to run in the field.

Parsnip Leaf-Miner (*Acidia fratria*). (See Radish).

Parsnip Web-Worm (*Depressaria heracliana*). An insect injurious to the seed as well as the stalks of plants, very often destroying young plants by eating the tender leaves.

Control: Spray with any of the arsenicals and destroy all wild carrots in vicinity.

PEA.

Aphis. (See Melon).

Pea Weevil (*Bruchus pisorum*). (For control see Bean).

Pod-Spot or **Blight** (*Ascochyta pisi*). The spots on pods are similar to bean anthracnose. Leaves are prominently spotted, and the stems are often rotted at the surface of the ground. The habits of this fungus are very similar to those of bean *Colletotrichum,* and it is to be controlled by the same measures.

Powdery Mildew (*Erysiphe polygoni*). There is a white cobweb-like growth on the leaves. It may be very destructive during warm moist weather about flowering time. Bordeaux mixture readily controls it.

PEACH.

1. **Aphids or Plant Lice.** Several species work upon the peach. For control see under Apple.

2. **Black Peach Aphis** (*Aphis persicae-niger*). This small black insect works both on the branches and roots and is to the peach what the woolly aphis is to the apple. It is controlled in the same manner, except that more dilute sprays must be used on account of the tender foliage.

Borers. The flat and round headed borers described under apple sometimes attack peach trees, but the most destructive is the Peach borer, (*Sanninoidea exitiosa*), which is a distinct species. It works mostly at the crown of the tree but may eat its way into the larger roots.

Control: The presence of borers is indicated by the gum which exudes from the hole where the borer enters. About the only remedy is to dig them out as recommended for apple borers. A common practice is to heap a mound of earth about the tree in late fall or early spring. This makes it necessary for the adult moth to lay her eggs on the trunk above the mound and the borers thus seldom reach the roots. In digging them out the mound is first removed. Painting as mentioned for the apple borer has more often proved disastrous to peach trees, which are less hardy than apples.

Brown Rot (*Sclerotinia* (*Monilia*) *fructigena*). This is the common rot of stone fruits.

Control: Destroy mummied fruit on the trees and ground. Prune to admit light and air, and thin the fruit. If possible, promptly remove and destroy the first rotted fruit and young shoots that may become blighted by the fungus. Spray with 8-8-50 self-boiled lime-sulphur three or four weeks after the petals fall, and again about one month before the fruit ripens. On late varieties another application may be made midway between these. Dormant cleansing sprays tend to check brown rot.

Crown-Gall. (See under Raspberry).

Curculio. Both the apple and plum curculio (which see) work on the peach. They not only do injury to the fruit themselves, but furnish an opportunity for brown rot to gain a foothold.

Control: Spray with a strong arsenical (2 to 5 lb. arsenate of lead to 50 gal. plus an equal amount of freshly slaked lime). 1st, Soon after petals fall; 2nd, Two or three weeks later. In small orchards the trees may be jarred in early morning when the adult insects will fall to the ground and may be caught on canvas and destroyed by throwing them into hot water or kerosene.

Fruit Bark Beetle (*Scolytus rugulosus*). This insect is also known as the shot hole borer because of the characteristic shot-hole-like punctures that it makes through the bark. It works between the bark and wood and preferably on dying trees or trees of low vitality, but many attack vigorous trees.

Control: Spraying is of no avail. Cut off and burn affected branches and prune, spray, and fertilize the trees to get them in strong, healthy, vigorous condition.

Leaf-Curl (*Exoascus deformans*). The leaves in spring are puckered and discolored, and fall prematurely.

Control: Cover limbs and twigs thoroughly with a good fungicide in early spring just before the buds swell. Lime sulphur preparations used for scale insects, or 5-5-50 Bordeaux is effective.

San José Scale. (See under Apple).

Scab or **Black Spot** (*Cladosporium carpophilum*). The numerous dark spots disfigure the fruit of certain varieties and produce hardening and cracking.

Control: Spray with 8-8-50 self-boiled lime-sulphur three or four weeks after the petals fall, and under severe conditions, a month later. These coincide with applications for brown-rot.

Terrapin Scale (*Lecanium nigro-fasciatum*). This insect has, in the past two or three years, developed to an alarming extent in the peach orchards of some parts of Pennsylvania and neighboring states. In the winter it may be readily recognized as a large hemispherical scale, mottled brown in color, appearing on the under side of the small twigs. In May eggs are laid underneath the scale, the mother gradually growing smaller until when the egg laying period is finished there remains but a mass of eggs underneath the hardened shell. About the first of June these eggs begin to hatch and the young crawl out on the under side of the leaves where they remain for six or eight weeks and then return to the under side of the smaller twigs where they spend the winter. The injury is done during the larva stage not so much because of their effect on the tree itself, as in the case of the San José scale, but because of the great quantity of honey dew secreted which forms an excellent host upon which develops a black fungus which causes an unsightly appearance of the fruit and renders it practically unsalable.

Control: Lime-sulphur seems to have little or no effect while the use of miscible oils is often attended by injury to the tree. This injury seems to be greater when the oil is applied during the fall or winter. Professor Symons of Maryland after extensive tests recommends a standard miscible oil to be applied at a strength of 1 to 15, just as late in the spring as possible before the buds open. He suggests, however, that this may be attended by some injury to the fruit buds. Dilute lime-sulphur applied during hatching time has been suggested, though so far as we know its use has not been justified by actual tests.

Yellows and **Little Peach.** Nothing is known definitely about causes of, or remedies for these obscure troubles. They are commonly held to be highly contagious. Affected trees are practically worthless; and it is prudent to remove them promptly, and burn them. Secure thrifty nursery stock having sound parentage.

GENERAL SPRAYING TREATMENT FOR PEACHES.

(1) Lime-sulphur winter strength (1.03) applied when trees are dormant for San José scale; or if Peach lecanium or Terrapin scale is present use an oil spray, instead of lime-sulphur, diluted 1 to 15 just as late as possible before buds start in the spring.

(2) Lead arsenate, 2 pounds to 50 gallons of water, plus 2 pounds freshly slaked lime just as calyces (shucks) are shedding for curculio.

(3) Self-boiled lime-sulphur (8-8-50) or lime-sulphur solution (sp. gr. 1.003) plus 2 pounds arsenate of lead to 50 gallons, for brown rot, scab and curculio. One month after petals fall.

(4) Self-boiled lime-sulphur (8-8-50) or lime-sulphur solution (1.003) one month before fruit ripens, for brown rot.

On late maturing varieties in wet seasons an additional spraying of lime-sulphur may be used midway between 3 and 4.

PEAR.

Aphids or Plant Lice. (See under Apple).
Blister Mite. (See under Apple).
Borers. (See under Apple).
Bud Moth. (See under Apple).
Canker Worm. (See under Apple).
Codling Moth. (See under Apple).
Curculio. (See under Apple).
Fall Web Worm. (See under Apple).

Fire Blight (*Bacillus amylovorus*). The bacteria flourish in the inner bark and cambium where external applications cannot reach them, but a winter drench seems sometimes to help prevent later infection. They live through the winter in the thick bark of larger limbs, are spread chiefly by insects, and gain entrance through wounds or blossoms.

Control: During the winter cut out all infected twigs and limbs. During the growing season keep a close watch for the appearance of blight and promptly cut out infected limbs a foot below the dead bark boundary, and dead bark from cankered areas. Disinfect all wounds and tools with corrosive sublimate or other good fungicide. Paint the larger wounds. Such prompt removal will prevent the spread down twigs to larger limbs and the girdling and death of the latter. Sod culture and avoidance of nitrogenous manures prevent succulent growth that is susceptible. Destroy neglected fruit trees that may harbor the disease.

Leaf-Blight (*Entomosporium maculatum*). Leaves become spotted and die. The fruit is also attacked. Spraying the developing leaves with Bordeaux mixture will control.

Leaf Miners. (See under Apple).

Oyster Shell Scale. (See under Apple).

Pear Psylla (*Psylla pyricola*). This minute insect feeds on the juices of the leaves and fruit. They appear early in the spring but do their greatest injury during May or early June. The adult, winged, insect passes the winter under the rough bark and begins laying eggs early in the spring, which hatch into a peculiar form known as a nymph which corresponds to the larva stage of most insects.

Control: Clean culture and the scraping of loose bark from the trees aids materially in its control. The following sprays are recommended*: (a) Kerosene emulsion (about 6%) or commercial miscible oil diluted with 12 to 15 parts of water or 1 lb. whale oil soap to four or six gallons of water. These should be applied with force just before buds open. (b) Lime-sulphur (1.03) applied as late as possible before the leaves appear. (c) Spraying with kerosene emulsion, whale oil soap or commercial tobacco preparations known as Black Leaf Tobacco Extract and Black Leaf 40, just after blossoming. All of the above have proved quite efficient in controlling this insect but the last is most commonly used.

Pear Slug (*Eriocampoides Limacina*). This is a shiny greenish-black larva often found on the leaves of pear, cherry and some other fruits during June and July. It feeds on the upper surface of the leaves.

Control: Spray with an arsenical poison or dust with freshly slaked lime.

San José Scale. (See under Apple).

Scab (*Venturia pirina*). This fungus affects fruit, leaves and twigs, and is very similar to apple scab.

Control: The same measures control the two. A winter drench of limbs seems more effective for pear scab, possibly because twig lesions may be in this instance a more usual source of new infection.

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* Parrot, Geneva Experiment Station.

Scurfy Scale. (See under Apple).

Tent Caterpillar. (See under Apple).

Tussock Moth. (See under Apple).

PLUM.

Aphis or Plant Lice. (See under Apple).

Black Knot (*Plowrightia morbosa*). The conspicuous black swellings produce spores rather continuously during the season, so that spraying for prevention is impracticable.

Control: Cut off and burn smaller limbs with knots twice a year, once in winter before March first, and again early in June to get the newly formed ones. On large limbs the knots may be cut out and the wounds disinfected and painted as indicated for pear blight.

Borers. (See under Peach).

Brown Rot. (See under Peach).

Bud Moth. (See under Apple).

Curculio (*Conotrachelus nenuphar*). The plum curculio differs from the apple curculio in that the adult is slightly smaller and has a shorter snout. The female lays her eggs on the side of the young plums and makes a characteristic crescent-shaped cut beneath it. When the larvae hatch, they enter the fruit at this opening, feed about the pit and cause the fruit to drop early.

Control: (See method for control under Peach).

Fruit Bark Beetle. (See under Peach).

San José Scale. (See under Apple).

Shot-Hole. (See under Cherry).

POTATO.

Colorado Beetle (*Leptinotarsa decemlineata*). Spray freely with arsenate of lead, 3 lb. to 50 gal. of water, or Paris green, ½ lb. to 50 gal. of water, with the addition of 2 lb. of lime.

Dry-Rot (*Fusarium oxysporum*). Affected tubers show a brown discoloration of the fibrous ring if cut across at the stem end. In storage they shrivel and slowly rot. The fungus lives in the soil, attacks the feeding roots first, and later enters tubers through their stems. If severely attacked, plants wilt and die suddenly; at other times they change color slowly as though ripening prematurely.

Control: Infected land should not be planted to potatoes for several years. Disinfect seed potatoes as for scab before they are cut. Examine by cutting the stem end, and reject all discolored ones. Use up an affected crop promptly, or store at a temperature near 40° F. in a dry place.

Early Blight (*Alternaria solani*). Definitely outlined circular brown spots with target-like markings develop anywhere on the leaflets and enlarge gradually, the rest of the leaflet becoming yellowed.

Control: Spray thoroughly with 4-4-50 Bordeaux mixture, beginning when the plants are six or eight inches high. Repeat at intervals of two weeks, increasing the strength to 6-6-50 for the third and later applications. Usually five applications will suffice. Control insects. Clean up trash.

Late Blight (*Phytophthora infestans*). This is not a common disease in Pennsylvania. The leaflets rot quickly, there is a downy fungous growth on the under side, and a disagreeable odor is emitted. Tubers rot in the field and in storage with a kind of dry rot.

Control Spray as for early blight, excepting that the two or three earliest applications are not needed for this disease. Do not plant tubers from an affected crop.

Potato Flea Beetle (*Epitrix cucumeris*). May be controlled by spraying with Paris green or arsenate of lead in Bordeaux mixture, using three pounds arsenate of lead or ¼ lb. Paris green to 50 gal. of the mixture.

Scab (*Oospora scabies*). This disease is caused by a soil fungus that may persist for several years. It is spread by planting scabby tubers.

Control: Because the infection is superficial, danger can be avoided by disinfecting seed potatoes before cutting by soaking for two hours in formalin, 1 pint to 30 gallons, or in corrosive sublimate, 4 ounces to 30 gallons. Select the smoothest potatoes for this treatment. On a large scale, formaldehyde gas disinfection has proven satisfactory. A clean crop will not be produced unless the clean seed is planted in clean soil. The fungus develops more and persists longer in alkaline soils than in neutral or slightly acid ones. Lime, wood ashes, and barnyard manure favor scab; green manuring and most chemical fertilizers hinder its development. In any case a rotation of several years' length should be followed on infested land.

Soft Rots. (Various causes). Several soft or wet rots commonly affect tubers in the field or after storage. They seem to be caused in each case by bacteria, and are not to be confused with the *Fusarium* or *Phytophthora* dry rot, although they often follow these as well as scab injury. Dig the potatoes as soon as possible, if wet weather prevails and they have been grown in heavy soil. Store in a dry, cool, well-ventilated place. Rotate crops, and avoid using seed potatoes from affected hills. If possible, use hardy strains.

Tip-Burn or **Leaf-Scorch.** This condition is often mistaken for the fungous blights. It is purely a functional disorder, resulting from lack of sufficient moisture supply for the leaf, and is marked by the dying and curling of the leaflets from the tips or margins. A check after rapid growth, drouth, insect bites, or root disease may cause this symptom. Increase the water retaining capacity of the soil by deep plowing, addition of humus, and frequent shallow cultivation in dry weather. Plant deep, and control insects.

QUINCE.

Aphids or Plant Lice. (See under Apple).
Black Rot and Rust. (See under Apple).
Blight. (See under Pear and Apple).
Borers. (See under Apple).
Bud Moth. (See under Apple).
Codling Moth. (See under Apple).
Curculio. (See under Apple).
Leaf Blight. (See under Pear).
San José Scale. (See under Apple).

RADISH.

Turnip Leaf-Miner (*Scaptomyza flaveola*). Clip infested leaves and burn.

RASPBERRY.

Anthracnose (*Gloeosporium venetum*). Numerous gray sunken spots occur on the canes.

Control: Spraying, to be effective, must be continued through the season, and is expensive. It is often more profitable to renew the plantings frequently, selecting sound plants, and putting them at a distance from infected rows. Cut out and burn all spotted canes as soon as the crop is gathered. Protect young shoots by spraying once or twice with 5-5-50 resin Bordeaux mixture. Destroy wild raspberry plants near by.

Cane Blight (*Leptosphaeria coniothyrium*). Canes wilt and die suddenly at about the fruiting season. Their bark shows ashy gray areas dotted with minute black specks. The measures given for anthracnose will control.

Cane Borer (*Oberia bimaculata*). This insect is the larva of a small beetle which during the month of June lays its eggs in the young canes first having girdled the cane near the top by making two rows of punctures about it about one-half inch apart. The larvae eat their way down the cane, killing it, and the following spring emerge as beetles.

Control: Affected canes may be easily distinguished in mid summer by the wilted tip above the girdled portion. Such canes should be cut and burned at once.

Several other insects attack the canes about the only control for which is to *cut out and burn* as soon as their appearance becomes manifest.

Crown-Gåll (*Bacterium tumefaciens*). Recent studies indicate the bacterial nature of crown-gall and its identity on peach, apple, grape and raspberry. The seriousness of it varies with conditions. Infected plants should not be planted. Often plants recover, and chances for spread in the field seem somewhat slight; but in close plantings like raspberry rows, it is a safe precaution to dig out and burn affected plants as they are detected. Infested land should not be planted soon with susceptible plants.

Rust (*Gymnoconia interstitialis*). Powdery yellow areas develop on leaves. The fungus persists in perennial parts of affected plants, and it is best to dig them out.

SQUASH.

Anthracnose. (See Cucumber).

Bacterial Wilt. (See Cucumber).

Downy Mildew. (See Cucumber).

Melon Aphis. (See Melon).

Pickle Worm. (See Melon).

Squash Vine Borer (*Melittia satyriniformis*). Damage is done by a white grub-like larva boring into the stems, causing them to rot.

Control: Cultural methods afford the only relief as insecticides are of little value and repellants practically useless. Plant as early as possible a few summer squashes as a trap crop. Fall plowing greatly reduces the species. Cutting out the borers may be resorted to in a home garden. Keep plants growing strongly by using fertilizers and draw soil up over base of vines to promote new root growth.

Squash Bug (*Anasa tristis*). The most common and widely distributed insect attacking the squash and other cucurbits.

Control: Hand picking the mature bugs and the crushing of eggs whenever found will help to control this pest. The young immediately after hatching may be killed by spraying with kerosene emulsion. The planting of trap hills and trapping under boards or chips, and covering hills with netting will help in their control.

Striped Cucumber Beetle. (See Cucumber).

STRAWBERRY.

Leaf Roller (*Phoxopteris comptana*). A larva of a moth which feeds upon the leaves, rolling them and causing them to turn brown.

Control: Cut and burn foliage after fruiting and spray with lead arsenate or Paris green.

Leaf-Spot (*Sphaerella fragariae*). The spots are gray with purplish borders. The disease is more serious on old beds. It is best controlled by making new plantings from sound plants well away from infected beds. If necessary, spray with 4-4-50 Bordeaux mixture at any time after the plants have become established. Old beds may be mowed after picking, the leaves raked thoroughly and burned, and the new growth protected with Bordeaux mixture. Varieties vary in susceptibility.

Root Borer (*Typophorus canellus*). A larva of a small beetle which feeds on the foliage in early spring, laying eggs in the ground which subsequently hatch into larvae which feed on the roots.

Control: Spray in early spring with Paris green or lead arsenate. Soil known to be infested should not be replanted for several years.

Saw-fly (*Harpiphorus maculatus*). The larva of this insect is a pale green worm which works on the foliage and may be distinguished from other worms which affect the strawberry by the number of legs (22).

Control: Spray with lead arsenate or Paris green before fruit sets or after picking or with hellebore during fruiting time. Dust with dry slaked lime.

White Grubs. These are the larvae of the well known June beetle. They sometimes feed on the roots of the strawberry.

Control: Fall plow early in September, and where numerous do not plant sod land but grow potatoes or some other hoed crop for a year.

SWEET CORN.

The Corn Ear-Worm (*Hetiothis obsoleta*). A well known enemy of corn, entering the ear and doing a great deal of damage.

Control: No good remedies known. Early planting suggested as late plantings in certain sections seem to secure greater injury. Fall plowing is also recommended.

Corn Root Aphis. A small green louse living on the roots and sucking the juices.

Control: Practice fall plowing. The use of kainit at the rate of 800 pounds per acre will also tend to eradicate the pest.

Smut (*Ustilago zeae*). Any young part of the plant above ground may become infected.

Control: Remove and destroy all smut masses just before the oldest break, and again when the corn is harvested. Barnyard manure easily becomes contaminated with this smut, thus spreading it to fields. When corn smut is serious use manure sparingly on corn land. Rotate crops. Seed treatment, as for other grain smuts is not effective.

TOMATO.

Damping-Off. . (See under Cabbage).

Flea Beetle. (See Eggplant or Potato).

Fruit-Rots (Various causes). End-rot of the fruit sometimes starts independently of any organism through apparent failure of the tissues to develop properly. Lack of water during fruiting is an important causal factor; and the loss can be reduced by supplying water, or by cultivating to conserve soil moisture. In other cases, fungi of several kinds are responsible for rotting of the fruit; and spraying with Bordeaux mixture or ammonical copper carbonate may be resorted to.

Leaf-Mold or **Mildew** (Cladosporium fulvum). This disease is often troublesome in greenhouses.

Control: Watch the leaves for the first appearance of the yellow spots with a gray or brownish mold underneath; and spray thoroughly with Bordeaux mixture, taking care to reach the under surfaces. Repeat every two weeks and substitute ammoniacal copper carbonate to avoid staining the fruit. See that the plants are not crowded and that moisture, light and ventilation are properly regulated. Gather and burn all refuse.

Leaf-Spot (*Septoria lycopersici*). Small brown spots occur on the older leaves, and these become yellow and die. Stems may also be attacked. Watch the seed bed for the beginning of the trouble, and spray promptly with Bordeaux mixture. When setting, pinch off affected leaves and others that would touch the ground. Keep the vines off the ground. Spray in the field with Bordeaux mixture or ammoniacal copper carbonate, so as to keep the leaves coated.

Mosaic Disease or Winter Blight. (Cause unknown). Leaves are distorted and splotched in an indefinite way, the tissue dying later. Brown spots develop on stems and fruit. Little can be said with definiteness about its control. It develops in greenhouses during the short winter days. Using wood ashes as fertilizer, and giving a minimum of water, have apparently checked the trouble. Marked soil acidity is to be avoided, and general sanitary precautions may well be taken.

Tomato Worm (*Phlegethontius quinquemaculata*).

Tomato Fruit Worm (*Heliothis obsoleta*). The above named worms are sometimes troublesome but can be controlled by hand picking or spraying early with Paris green or arsenate of lead.

Wilt Diseases (*Fusarium sp.* and bacteria). Here are included several distinct diseases caused by different organisms. They have the common habits of inhabiting the soil, entering through the roots, and spreading in the sap-tubes so as to choke them and cause wilting and death. Spraying is ineffective. Destroy affected plants promptly, clean up all trash, and practice a long rotation. In greenhouses, infected soil should be sterilized or fresh soil introduced, if tomatoes are to be planted again.

White Fly. A small white fly doing considerable damage under glass. Paint pipes with a paste or air-slaked lime 2 parts and sulphur 1 part with enough water to make a paste.

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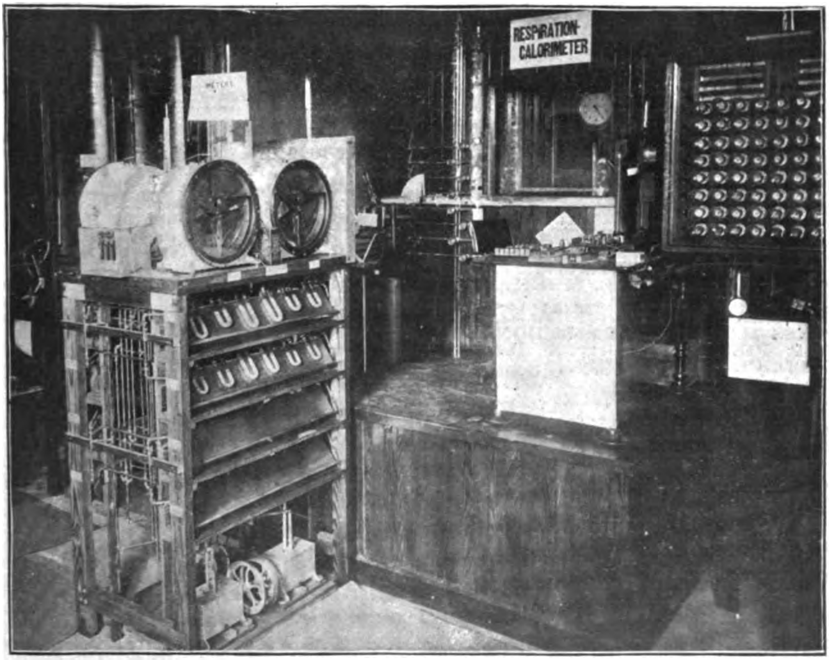

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BULLETIN No. 111

THE MAINTENANCE RATION OF CATTLE[1]

By **HENRY PRENTISS ARMSBY**, Director of the Institute of Animal Nutrition.

In a bulletin[2] bearing this title, published in 1898, the writer discussed the data regarding the maintenance ration of cattle which were available up to that time, including the results of a series of experiments at this Station extending over five years. Investigations upon cattle by the Institute of Animal Nutrition, which have been in progress since 1902 and in which the income and outgo of matter and of energy have been determined with the aid of the respiration calorimeter, have incidentally afforded data regarding the maintenance ration which are in certain respects unique. Some additional results have also been reported by other investigators, while the aspect of the whole subject has been considerably modified by the scientific progress of the past dozen years. In the following pages an attempt is made to outline the present state of knowledge on this subject from the more recent point of view.

DEFINITION OF MAINTENANCE.

Feed is supplied to farm animals either that they may yield products useful to man as materials for human food and clothing or that they may serve him by the performance of mechanical work.

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[1] Investigations under the Adams Act in cooperation with the Institute of Animal Nutrition and the Bureau of Animal Industry of the U. S. Department of Agriculture.

[2] Pennsylvania Experiment Station, Bulletin No. 42.

But much as a factory must first be supplied with enough power to keep in motion the shafting, belting and machinery in general before any product can be turned out, so the animal mechanism must be provided with sufficient feed to maintain the processes essential to life before any continued production is possible. The amount of feed required for this purpose is called the maintenance ration of the particular animal. It is the quantity of feed necessary simply to support the animal when doing no work and yielding no material product. If an animal receiving exactly a maintenance ration were subjected to a so-called balance experiment, there would be found an exact equality between income and outgo of ash, nitrogen, carbon, hydrogen and energy, showing that the body was neither gaining nor losing protein, fat, carbohydrates nor ash.

The word maintenance is sometimes used popularly in another sense to signify the total amount of feed required, for example, by a horse in order to perform his daily work or by a calf in order to make a normal growth. It is important to grasp the idea that, in its technical sense, the maintenance ration means the minimum required simply to sustain life. The feed of the horse or calf would, from this point of view, be regarded as consisting of two portions. One of these is the maintenance ration, which if fed by itself would just support the horse at rest or the calf without growth; the other is the productive portion of the ration, by means of which work is done or growth made. To recur to the illustration of the factory, the maintenance ration keeps the empty machinery running, while the additional feed furnishes the power necessary to turn out the product.

SIGNIFICANCE OF THE MAINTENANCE RATION.

It might seem at first thought that not much importance attaches to a study of maintenance. The animal kept on a maintenance ration yields no direct economic return and hence simple maintenance feeding should be avoided, so far as practicable, and when it appears desirable to practice it the observation of the skilled stockman, especially if supplemented by occasional weighings, will usually suffice to determine whether or not the end is being attained. Nevertheless, the subject has significance both for practice and for science.

A very considerable fraction of the feed actually consumed by farm animals—on the average probably fully one-half—is applied simply to maintenance. But if half of the farmer's feed bill is expended for maintenance, it is clearly important for him to know something of the laws of maintenance,—how its requirements vary as between different animals, how different feeding stuffs compare in value for maintenance, etc.,—as well as to understand the principles governing the production of meat, milk or work from the other half of his feed.

From the scientific point of view, the matter is of even greater importance. In any rational study of the laws of nutrition, it is plainly inadmissible to attempt to establish general principles by a comparison of the food with one of its effects, viz., production, while ignoring entirely its other effect, viz., maintenance. Failure to appreciate this fact is responsible for many misleading deductions from feeding experiments in the past. It has been quite usual to compare the results of such experiments by computing the ratio of feed consumed to product yielded—i. e., either the feed consumed per pound of gain or the gain produced per pound of feed consumed. Such a comparison, however, may give an entirely distorted idea of the real teachings of an experiment. Suppose, for example, that in a fattening experiment the energy values of two rations (computed according to the table on page 15) and the gains made were as follows:

	First ration	Second Ration
Energy value of feed	9.0 Therms	10.5 Therms
Daily gain	1.0 lbs.	1.5 lbs.

Compared in the way just indicated, the feed energy required to produce one pound of gain was

In the first experiment, 9 Therms
In the second experiment, 7 Therms

or the second ration appears to have been superior to the first by about 29 per cent. If, however, account be taken of the fact that in each experiment a certain portion of the energy value of the feed, 6 Therms, for example, was required simply to maintain the animal, a very different comparison is obtained, viz.,

	First ration	Second ration
Energy value of feed	9.0 T.	10.5 T.
Energy expended in maintenance	6.0 T.	6.0 T.
Surplus left for production	3.0 T.	4.5 T.
Daily gain	1.0 lb.	1.5 lb.
Surplus energy per pound of gain	3.0 T.	3.0 T.

The real value of the two rations per unit is thus shown to have been the same. The economic advantage of the second was not due to any higher nutritive value, but simply to the fact that more of it was eaten. Similarly, if we suppose the foregoing results to have been obtained, not with two different rations but with two different animals on the same ration, the experiment does not show that the second animal digested or assimilated his feed any more efficiently than the first but simply shows the economic advantage of a larger consumption of feed. It scarcely need be added that the same principle applies in all cases of productive feeding, as has recently been shown in a very striking manner by Eckles[1] in experiments upon dairy cows.

THE MAINTENANCE REQUIREMENTS.

Unlike the operations of a factory, which cease when the power is shut off, the activities of the animal do not stop when food is withdrawn, but continue for a variable length of time at the expense of the tissues of the body. Men have fasted voluntarily for 30 days or more without obvious permanent ill effects and there are records of dogs having survived fasting periods of from 60 to 90 days. In the fasting animal at rest, the vital activities are reduced as it were to their simplest terms, practically only those functions being active which are essential to continued life. In such a fasting animal the power necessary to operate the machinery of the body is derived from the breaking down and oxidation of the materials of the body. It is as if the materials of the factory itself were being cut up and used as fuel under the boilers.

Scientific investigation confirms common observation in showing that it is chiefly the fat of the body which is used in this way. Fat is the body's surplus of fuel material, laid aside when food is abundant in order to serve precisely this purpose in time of scarcity. The gradual emaciation of the fasting or insufficiently fed animal is too familiar to require more than mention.

But while the body fat is usually the chief material used up by the fasting animal, it is not the only one. As is well known, the active tissues of the body consist chiefly of protein and it appears that all their activities are necessarily accompanied by the breaking down and oxidation of more or less of their protein, so that the fasting animal is continually losing protein as well as fat. If the animal is in good condition at the outset, it has been found that usually only about 10 to 15 per cent. of the energy required for the vital activities during fasting is derived from protein, the remainder being drawn from the body fat. If, however, the body was originally deficient in fat, or when it becomes so as a result of fasting, the protein is used more freely, so that when the body becomes practically exhausted of fat almost the entire supply of energy may be derived from the breaking down of protein. In other words, in the absence of the special fuel material (fat) in the body, its working machinery begins to be used and this naturally leads to a speedy death. On the other hand, some breaking down of protein always takes place however much fat the body may contain. This unavoidable loss of protein in fasting may be roughly compared to the wear of the working parts of a machine. Finally, there is likewise a continual loss of ash ingredients as well as of protein from the organs of the fasting animal.

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[1] Missouri Experiment Station, Research Bulletin No. 2.

The necessary operations of the vital machinery of the fasting animal, then, require:

First, certain rather small amounts of protein and ash.

Second, a certain supply of energy, of which the greater part is usually supplied by the breaking down of fat, but to which the body protein contributes to a greater or less extent.

Experiments like those described on subsequent pages, in which the amounts of protein and energy required for the vital functions of the fasting animal are determined, either directly or indirectly, give what may be called the maintenance *requirements*; that is, they show the minimum amounts necessarily expended for the mere continuance of life. The maintenance requirements in this sense are to be distinguished from the maintenance *ration*, *i. e.*, from the amount of food of any given kind which must be supplied to the animal in order to satisfy these requirements and so prevent a loss of protein, ash or fat from the body.

THE DETERMINATION OF THE MAINTENANCE REQUIREMENTS.

With animals such as man, carnivora or swine, having a comparatively simple digestive apparatus and living on relatively concentrated food, the maintenance requirements in the foregoing sense can be determined without special difficulty in a relatively short period of fasting, although an exact experiment involves the use of a respiration apparatus or respiration calorimeter. The total amount of heat produced by such an animal, whether determined directly or by calculation, shows how much energy it is drawing from the materials of its body, while the amount of nitrogen contained in the urine shows how much protein is being broken down.

With cattle, owing to their voluminous and complicated digestive organs and the considerable amount of feed which the latter still contain even after long fasting, this method is not practicable. As regards the protein requirement, all that is possible is to determine by trial, in the manner illustrated on subsequent pages, the amount of digestible protein in the feed which suffices to prevent a loss of protein from the body. It is possible, however, by an indirect method to determine the energy requirement of fasting cattle.

Indirect determination of energy requirement.

A steer consumed per day in two successive periods 7.05 pounds and 11.68 pounds of timothy hay, neither ration being sufficient to maintain the animal. The amount of heat produced daily in each period, as measured by means of the respiration calorimeter, was:

	Hay eaten lbs.	**Heat produced Therms**[1]
Period IV	11.68	9.70
Period III	7.05	8.06
Difference	4.63	1.64

The addition of 4.63 pounds of hay in Period IV increased the heat production of the steer by 1.64 Therms, or at the rate of 0.35 Therms for each pound of hay. This is entirely in accord with the well established fact that an increase in the amount of feed consumed tends to cause an increase in the heat production of an animal. If, now, instead of adding more hay to the ration of Period III, hay had been withdrawn from it, it may be assumed that the heat production would have decreased at the same rate as it actually increased. If, then, it had been possible to withdraw all the feed, the heat production would have been diminished by $0.35 \times 7.05 = 2.47$ Therms; that is, the heat production of the fasting animal would have been $8.06 - 2.47 = 5.59$ Therms. By thus comparing two periods upon different amounts of feed, it is possible to get indirectly the amount of energy required to carry on the necessary vital processes, i. e., the maintenance requirement as defined in the previous paragraph.

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[1] A therm, equal to 1000 large calories, is the amount of heat required to raise the temperature of 1000 kilograms (2204 pounds) of water 1°C.

The average weight of the steer was 824 pounds. For purposes of comparison, it is usual to compute results to an average live weight of one thousand pounds. It has been shown that the maintenance requirement is approximately proportional to the surface of an animal rather than to its weight, while the surface is approximately proportional to the cube root of the square of the weight. Computed in this way, the maintenance requirement of this steer for energy per thousand pounds live weight was:

$$5.59 \times \sqrt[3]{\left(\frac{824}{1000}\right)^2} = 6.50 \text{ Therms.}$$

The results of eight trials of this sort on three different animals, none of which were fat, were as follows:

Maintenance requirements of steers—energy.

Year	Animal	Available Energy for Maintenance per 1000 Lbs. Live Weight. Therms	Feed
1903	I	6.076	Clover hay
1904	I	7.321	" "
1905	A	6.231	Timothy hay
1905	B	7.058	" "
1906	A	5.695	" "
1906	B	6.378	" "
1907	A	4.860	" "
1907	B	6.496	" "
Average of all..........		6.264	
Average, omitting 1904		6.113	
Average, 1905-07.......		6.121	

THE MAINTENANCE RATION.

As already defined on page 7, the maintenance ration is the quantity of feed which will supply sufficient protein and energy in available forms to meet the maintenance requirements of the body. Obviously, the amount of the maintenance ration will depend both upon the magnitude of the maintenance requirements and upon the availability of the protein and energy of the materials composing the ration.

The maintenance ration of protein.

It seems to have been satisfactorily shown that a supply of digestible protein in the feed equal to the amount broken down during fasting is at least sufficient for a maintenance ration. As already noted, however, this quantity cannot be determined directly for cattle. The only available method, then is to try various amounts of protein and see how low the supply can be reduced without causing a loss of protein from the body. In considering the results of such experiments, two points must be borne in mind.

First, if more protein is supplied to the mature animal than it needs for its maintenance, the surplus is practically all broken down and oxidized as fuel to supply energy. The mere fact, therefore, that there is no loss of body protein on a given ration, while it shows that the protein supply is ample, does not show that a less quantity would not be sufficient.

Second, when there is an inadequate supply of carbohydrates and fat in the food, protein which would otherwise be used for maintenance may be broken down and used as fuel. The protein supply can be reduced to its lower limit only when there is a liberal supply of fuel material in the ration.

The question to be considered, then, is what is the least amount of protein which has sufficed to maintain cattle when the total food supply was ample to yield the necessary energy.

Wolff's standard for maintenance, long current, of 0.7 pounds digestible crude protein per 1000 pounds live weight was based upon experiments by Henneberg & Stohmann in 1858 with the addition of an allowance for the fact that their experiments were made at a relatively high temperature. Wolff's standard, however, was intended as a guide for actual maintenance feeding rather than as an expression of the minimum protein requirement, which, as later experiments show, may be reduced considerably below Wolff's standard.

Of the more recent experiments, those of Kühn and Kellner at the Moeckern Experiment Station were the earliest. Of the eight animals experimented upon, seven gained fat during the experiment, showing that the rations contained a sufficient quantity of non-nitrogenous nutrients, while in the remaining cases the loss of fat was relatively small. Dividing the experiments into groups according to the amounts of digestible protein consumed, the following average results per thousand pounds live weight are obtained:

Daily gain or loss of body protein.

	Average Digestible Protein Consumed Lbs.	Average Gain or Loss of Protein by Animal Lbs.
Average of 5 animals.	0.59	+ 0.089
Average of 3 animals.	0.32	− 0.085

Of the trials at this Station reported in Bulletin No. 42, Experiments II, VI and VII showed a slight gain of protein by each of the three animals experimented upon, while in Experiment VIII the losses of protein were very small, except for Steer No. 3. Omitting this latter case, the daily averages for each experiment, per thousand pounds live weight, were:

Daily gain of body protein.

	Average Digestible Protein Consumed Lbs.	Average Gain of Protein by Animal Lbs.
Experiment II	0.40	0.05
Experiment VI	0.59	0.06
Experiment VII	0.29	0.06
Experiment VIII	0.50	0.002

In the series of experiments with the respiration calorimeter, the results of part of which have been given on page 9, there were two in which 0.44 pound of digestible true protein per thousand pounds live weight sufficed for maintenance. In the remaining experiments considerbly larger amounts were consumed, so that, as pointed out on page 11, the results do not show the minimum needed.

In experiments by the Laboratory for Agricultural Research in Copenhagen, protein maintenance was secured with two dry cows on rations containing an average of only 0.23 pound digestible crude protein per thousand pounds live weight. Their experiments on milking cows, however, indicated a higher figure, viz., between 0.45 and 0.60 pound.

In the light of the results just enumerated the conclusion appears justified that a ration supplying a minimum of about 0.6

pound digestible crude protein or 0.5 pound digestible true protein will suffice for the protein maintenaince of mature cattle.

The maintenance ration of energy.

It has been shown that the maintenance ***requirement*** is equivalent to the amount of energy consumed during fasting, and that for thin mature cattle this averages about 6.1 Therms per thousand pounds. We have now to inquire how much feed must be supplied to meet this requirement.

Plainly, the value of a feeding stuff so far as it serves as fuel, depends, in the first place, on how much total energy can be secured from it in the form of heat. This can be measured without difficulty by burning the substance, and measuring the heat produced. The following are the results of a few such determinations:

Total energy in 100 pounds[1].

Timothy hay	175.1 Therms
Clocer hay	173.2 Therms
Oat straw	171.0 Therms
Wheat straw	171.4 Therms
Corn meal	170.9 Therms
Oats	180.6 Therms
Wheat bran	175.5 Therms
Linseed meal	196.7 Therms

Available energy: But the value of a fuel depends also upon how much of the energy which it contains can be used. Hard coal contains plenty of energy, but it would not be of much use to run a gasoline engine. Wheat straw contains fully as much energy as corn meal, but much of that energy cannot be utilized by the animal machine.

Two causes combine to affect the availability of the energy contained in feeding stuffs.

First, more or less of the feed escapes from the body unburned. If a coal is of such quality that portions of it drop through the grate unconsumed, and if smoke and combustible gases are carried off through the stack, it is evident that a ton of it will supply far less heat to the boiler than it would if the combustion were perfect. The case of the feeding stuff is similar. Much of even the best feeding stuffs escapes digestion and is excreted in the dung, carrying with it a corresponding quantity of the chemical energy of the feed. More or less incompletely burned material is also contained in the urine, while ruminants, and to a certain extent horses, also give off combustible gases, arising from fermentations in the digestive tract. Thus about 22 per cent, of the energy of corn meal and fully 55 per cent. of that of average hay has been found to escape in these ways.

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[1] With 15 per cent. moisture.

Second, the animal body has to extract its real fuel material from its feed, separating it from the relatively large proportion of useless material which it excretes. To effect this separation requires work and consumes energy, and this energy, of course, is not available for other purposes. The case is somewhat as if the gasoline engine had to distill its own gasoline and separate it from impurities. Moreover, when the animal eats more feed than is required simply to furnish energy to run its machinery, and hence is able to produce meat or milk, the process of converting the food into suitable forms to store up in the body may require a further expenditure of energy.

It is not, then, the total energy contained in a feeding stuff which measures its value for maintenance, but what remains after deducting the losses in the unburned materials of the excreta and the energy expended in extracting the real fuel materials from the feed and transforming them into substances which the body can use or store up. For example, while 100 pounds of corn contain, as stated, about 170.9 Therms of chemical energy, only about 88.8 Therms remain, after all these deductions have been made, to represent the actual value of the corn as a source of energy to the organism.

Determination of available energy: The amount of energy in available form which a feeding stuff contains is determined by the same sort of experiments as those which serve to determine indirectly the maintenance requirement. Thus in the example on page 8, the steer in both periods was on a sub-maintenance ration, i. e., he was breaking down daily more or less of his own tissue, especially his fat, to supply energy. As determined directly with the respiration calorimeter, the actual daily amount of energy thus derived from the destruction of body tissue was as follows:

	Hay eaten lbs.	**Energy supplied from body tissue** Therms
Period IV	11.68	0.371
Period III	7.05	2.495
Difference	4.63	2.124

Thé addition of 4.63 pounds of hay to the basal ration of Period III diminished the draft on the body tissues by 2.124 Therms, this being equivalent to 0.459 Therm for each pound of hay. Obviously, the latter number expresses the value of one pound of this hay for maintenance and to maintain a steer with an average requirement of 6.1 Therms would plainly require 6.1 ÷ 0.459 = 13.29 pounds of this particular timothy hay.

Kellner at the Moeckern Experiment Station has made a large number of similar experiments on heavier rations which produced more or less gain by the animals. For example, an experiment in which oat straw was added to a basal ration gave the following results:

	Oat straw eaten lbs.	Energy stored in gain of body tissue Therms
Period 1	8.8	3.535
Period 3 (basal ration)	0	1.777
Difference	8.8	1.758

Each pound of straw produced a gain of tissue equivalent to 0.2 Therm of energy. This is its "production value" as part of a fattening ration.

It is not yet certain that the production values obtained in this way correspond exactly with the values below the point of maintenance obtained in the manner described in the previous paragraph. The indications are, however, that the two agree substantially for concentrated feeds, while for the coarse fodders the production value may be somewhat less than the maintenance value. For the present, however, and until more extensive determinations of maintenance values are available, it appears advisable to disregard this possibility and to consider the maintenance and production values as for practical purposes identical. Upon this assumption, and largely upon the basis of Kellner's results, the following table[1] has been computed, showing approximately the energy values either for maintenance or for production of a number of the more important feeding stuffs.

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[1] Originally published in Bulletin No. 71 of this Station and reproduced in Farmers' Bulletin No. 346 of the U. S. Department of Agriculture.

Dry matter, digestible protein, and energy values per 100 pounds.

Feeding stuff.	Total dry matter.	Digestible true protein.	Energy value.
Green fodder and silage:	*Pounds.*	*Pounds.*	*Therms.*
Alfalfa	28.2	2.50	12.45
Clover—crimson	19.1	2.19	11.30
Clover—red	29.2	2.21	16.17
Corn fodder—green	20.7	.41	12.44
Corn silage	25.6	0.88	16.56
Hungarian grass	28.9	1.33	14.76
Rape	14.3	2.16	11.43
Rye	23.4	1.44	11.63
Timothy	38.4	1.04	19.08
Hay and dry coarse fodders:			
Alfalfa hay	91.6	6.93	34.41
Clover hay—red	84.7	5.41	34.74
Corn forage, field cured	57.8	2.13	30.53
Corn stover	59.5	1.80	26.53
Cowpea hay	89.3	8.57	40.76
Hungarian hay	92.3	3.00	44.03
Oat hay	84.0	2.59	26.97
Soy bean hay	88.7	7.68	38.65
Timothy hay	86.8	2.05	33.56
Straws:			
Oat straw	90.8	1.09	21.21
Rye straw	92.9	.63	20.87
Wheat straw	90.4	.37	16.56
Roots and tubers:			
Carrots	11.4	.37	7.82
Mangel-wurzels	9.1	.14	4.62
Potatoes	21.1	.45	18.05
Rutabagas	11.4	.88	8.00
Turnips	9.4	.22	5.74
Grains:			
Barley	89.1	8.37	80.75
Corn	89.1	6.79	88.84
Corn-and-cob meal	84.9	4.53	72.05
Oats	89.0	8.36	66.27
Pea meal	89.5	16.77	71.75
Rye	88.4	8.12	81.72
Wheat	89.5	8.90	82.63
By-products:			
Brewers' grains—dried	92.0	19.04	60.01
Brewers' grains—wet	24.3	3.81	14.82
Buckwheat middlings	88.2	22.34	75.92
Cotton-seed meal	91.8	35.15	84.20
Distillers' grains—dried—			
Principally corn	93.0	21.93	79.23
Principally rye	93.2	10.38	60.93
Gluten feed—dry	91.9	19.95	79.32
Gluten meal—Buffalo	91.8	21.56	88.80
Gluten meal—Chicago	90.5	33.09	78.49
Linseed meal—old process	90.8	27.54	78.92
Linseed meal—new process	90.1	29.26	74.67
Malt sprouts	89.8	12.36	46.33
Rye bran	88.2	11.35	56.65
Sugar-beet pulp—fresh	10.1	.63	7.77
Sugar-beet pulp—dried	93.6	6.80	60.10
Wheat bran	88.1	10.21	48.23
Wheat middlings	84.0	12.79	77.65

Maintenance ration in terms of available energy: If the foregoing results are correct, then a ration which, according to the table, furnishes 6.1 Therms of energy value should be an average maintenance ration for a thousand pound steer, provided, of course, it contains sufficient protein. There are a number of experiments on record by means of which the truth of this can be tested. The most extensive trials of this sort are the Moeckern experiments of Kühn and Kellner already mentioned, made with the aid of a respiration apparatus. The results of the respiration experiments at this institute of course show an agreement because they are the basis upon which the maintenance requirement is computed.

It should be understood that it is only rarely and by accident that the exact maintenance ration can be hit upon in such an experiment. Practically these refined methods always show some gain or loss by the animal, the energy equivalent of which can be estimated from the results of the respiration experiments. The energy value of the feed consumed is, therefore, corrected by adding to it the energy of the loss or subtracting from it the energy of the gain in order to obtain the exact maintenance requirement.

The energy values required for the maintenance of eight mature cattle, computed substantially in the manner just indicated[1], were as shown in the following tabulation. The very high requirement indicated for Ox B was doubtless due to the fact that he never laid down during the respiration experiments; accordingly he has been omitted in computing the average. It will be seen that the average result and the range of variation agree well with those obtained in the experiments at this Institute tabulated on page 9.

Energy requirements for maintenance—per 1000 pounds live weight.

Ox V	5.50 Therms
Ox B	8.39 Therms
Ox A	5.91 Therms
Ox IV	7.32 Therms
Ox III	6.06 Therms
Ox II	6.60 Therms
Ox VI	5.31 Therms
Ox XX	6.67 Therms
Average, omitting Ox B	6.20 Therms

There are also on record a number of experiments in which the sufficiency of a ration for maintenance has been judged by its effect upon the live weight. As is well known, the live weight of an animal is a very uncertain indication of the results of short feeding periods. When, however, the weight of a mature animal is maintained with but little variation through a long period, it is safe to consider that the average ration consumed approximates very closely to an exact maintenance ration. This is not true, however, of young animals, as has been shown by Waters. Such animals may grow at the expense of their fat tissue on an insufficient ration, maintaining their live weight by an increase in the water content of the body.

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[1] A more exact discussion of the method of comparison will appear in a bulletin of the Bureau of Animal Industry of the U. S. Dept. of Agriculture, entitled "The Maintenance Requirements of Farm Animals".

Such experiments are those of the writer[1], of Haecker[2] and of Evvard[3]. For the present purpose a detailed description of the experiments appears unnecessary. The results are summarized in the following table; all of them refer to thin animals.

Energy requirement of cattle for maintenance.
(per 1000 lb. live weight.)

	Number of Animals	Number of Single Trials	AVAILABLE ENERGY PER DAY		
			Maximum. Therms	Minimum. Therms	Average. Therms
Respiration experiments					
Armsby & Fries	3	7	7.06	4.86	6.11
Kellner	7	7	7.32	5.31	6.20
Totals and averages	10	14	7.19	5.09	6.16
Live weight experiments					
Armsby (Coarse fodder)	3	10	7.60	6.62	7.02
Armsby (much grain)	3	3	6.26	4.88	5.62
Haecker	3	5	6.45	5.30	5.71
Evvard, 60 day expt.	3	3	7.85	6.45	7.18
Evvard, 362 day expt.	1	1	——	——	8.09
Totals and averages	10	22	7.04	5.81	6.72

The average of the live weight results is greater than the average of the respiration results on account of a single exceptionally high result. The average of the other experiments is 6.31 Therms as compared with 6.16 Therms for the respiration experiments.

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[1] Penna. Expt. Station, Bulletin No. 42.
[2] Minnesota Expt. Station, Bulletin No. 79.
[3] Thesis for degree of M.S., University of Missouri, 1909.

SUMMARY.

On the basis of the results recorded in the foregoing pages, it is believed that the average maintenance ration of thin cattle may be formulated with a considerable degree of accuracy as follows:

Average maintenance ration of cattle.

(per 1000 lb. live weight.)

Digestible crude protein per day....	0.5 lb
Energy value per day................	6.2 Therms

FACTORS AFFECTING THE MAINTENANCE REQUIREMENT.

It is apparent from the foregoing results that while it is possible to state with a considerable degree of accuracy the average maintenance ration of cattle, individual cases may vary considerably from the average. It is desirable, therefore, to consider briefly some of the causes of these variations.

Muscular activity.

Probably the most important of these factors is muscular activity. All muscular work is done at the expense of energy derived from the oxidation of body material, and no other factor influences so largely the amount of tissue thus used up. In maintenance, of course, an animal does no work in the ordinary sense, but notwithstanding there is necessarily more or less muscular activity which tends to increase the maintenance requirement.

Standing and lying: One of the most marked examples of the effect of muscular exertion is furnished in the case of cattle by a comparison of the standing and lying positions. In experiments at this Institute it has been observed that a steer when standing has produced from 28 to nearly 65 per cent. more heat than the same steer when lying down, this heat of course arising from the combustion of materials of the body or of the feed. Similar results have been obtained elsewhere in experiments upon dogs and somewhat less marked ones in experiments upon men. While some experimenters have failed to find with ruminants a correspondingly large increase in the carbon dioxid given off during standing as compared with lying, the general fact that standing increases the heat production is unquestioned. It is clear, then, that of two steers, one of which lies down for 12 hours and the other for 8 hours out of the 24, the former will, other things being equal, require less energy for maintenance. In the experiments at this Institute, reported on page 9 of this bulletin, the maintenance requirement has been corrected as accurately as possible to an average period of twelve hours standing out of the twenty-four. In the other results mentioned on page 17, this factor has not been taken into account. An example of the apparent effect of this factor is seen in the results upon Ox B in Kellner's experiments, which, as noted, stood throughout the respiration trials.

Temperament: The nervous, restless animal is continually expending energy in a variety of unnecessary movements which may very materially increase the amount of fuel material necessary for his maintenance as compared with the quieter and more phlegmatic animal. Zuntz & Hagemann, for example, report a respiration experiment upon a horse in which the restlessness caused by the presence of a few flies in the chamber of the apparatus increased the amount of body material oxidized by fully 10 per cent.

The influence of temperament seems to be illustrated by the experiments at this Institute in 1905-07. Steer A of those experiments was a pure-bred beef animal of an unusually quiet disposition, while Steer B was a scrub of a decidedly nervous temperament. The maintenance requirements of these two animals per thousand pounds live weight, as shown in the table on page 9, were as follows:

Available energy required for maintenance.

	STEER A Pure-bred Beef Steer	STEER B Scrub
1905	6.23 Therms	7.06 Therms
1906	5.70 "	6.38 "
1907	4.86 "	6.50 "
Average	5.60 "	6.65 "

Like the temperament, any external conditions tending to affect the degree of muscular activity will also tend to affect the maintenance requirement. The steer confined in a stall, for example, is likely to take less muscular exercise and, therefore, to require a smaller amount for maintenance than one simply confined to a pen or an open yard. The animal comfortably bedded and thereby induced to spend much of his time in lying down will consume a smaller portion of his feed for maintenance than one kept under less comfortable conditions. Any sort of excitement is likely to be paid for by increased muscular activity and correspondingly increased consumption of food for maintenance.

Condition.

The condition of an animal as the word is commonly used is practically synonymous with the amount of fat tissue carried. Kellner, in addition to the experiments already mentioned, investigated the maintenance requirement of three fat animals, including one (Ox B) of those whose requirements in the thin state were determined. His results were somewhat contradictory. Ox B showed a lower requirement per thousand pounds live weight when fat than when thin, but the average for three fat animals was materially higher than that for thin animals, namely 8.85 Therms available energy per thousand pounds live weight. Evvard's live weight experiments also included a second sixty-day trial upon the same three animals partially fattened which showed a maintenance requirement of 9.07 Therms as compared with 7.18 Therms in the thin state.

External temperature.

As the experiment cited on page 8 illustrates, the consumption of feed is a source of heat to the animal and this heat aids in maintaining the normal body temperature. It has been clearly shown that at temperatures in the neighborhood of 60°F. a steer on a maintenance ration is producing considerably more heat than is necessary to maintain his body temperature. If the surrounding temperature falls, it is evident that for a time no increased heat production would be necessary, but sooner or later a point would be reached below which increased oxidation of feed or tissue would be required for the sake of additional heat production, although just what this temperature is has not been determined.

With animals consuming a heavy ration, fattening steers for example, the food consumption is the source of a large amount of heat and it has been clearly demonstrated that such animals may be exposed to a very considerable degree of cold without leading to the consumption of any additional material for the sake of heat production alone. In such cases, therefore, the maintenance requirement would not be increased until a much lower temperature was reached than in the case of the animal on a simple maintenance ration.

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The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 112

BEEF PRODUCTION IN PENNSYLVANIA

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
NOVEMBER, 1911

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 112

BEEF PRODUCTION IN PENNSYLVANIA

By W. A. COCHEL

Beef cattle should be considered as machines for reducing farm crops to a more concentrated market product. Through a series of years, they will return a greater total profit than is secured from marketing crops in their original form, and in addition will build up the fertility of the land so that greater crops can be produced. This is in reality the largest source of profit from handling beef cattle.

In the development of an agricultural country, beef cattle are produced in sections so remote from market that the cost of transportation of farm crops overbalances the profit in growing them. Because of the large volume of grass and forage crops which they consume, the distance which they can be driven, their freedom from contagious and infectious diseases, and their ability to withstand periods of food shortage and unfavorable weather, beef cattle are especially adapted to the utilization of the products of the soil in frontier sections. As the country develops, transportation improves, and markets for special crops become established, diversified farming replaces the grazing industry, the production of beef cattle decreases and farmers turn their attention to finishing cattle for market, which have been produced on cheaper, though possibly just as productive land. The importance of maintaining fertile soil and the practical impossibility of so doing, without feeding a large proportion of the roughage produced and returning manure to the land, causes many farmers to fatten cattle for market although they may derive no immediate profit from the transaction.

After all of the available farming land has been brought under cultivation, then the production of beef cattle is limited to those sections especially adapted to the business, where climate and soil are favorable to the growth of pastures and meadows, water is abundant, and the topography of the country is such that it is impractical to plow because of soil erosion. A study of the agricultural development in the United States shows that the tendency has been to eliminate breeding herds of beef cattle, first from the eastern, then from the central and middle western states, depending always upon the cheaper lands of the West to furnish feeding steers to consume the farm products where beef breeding herds were formerly maintained.

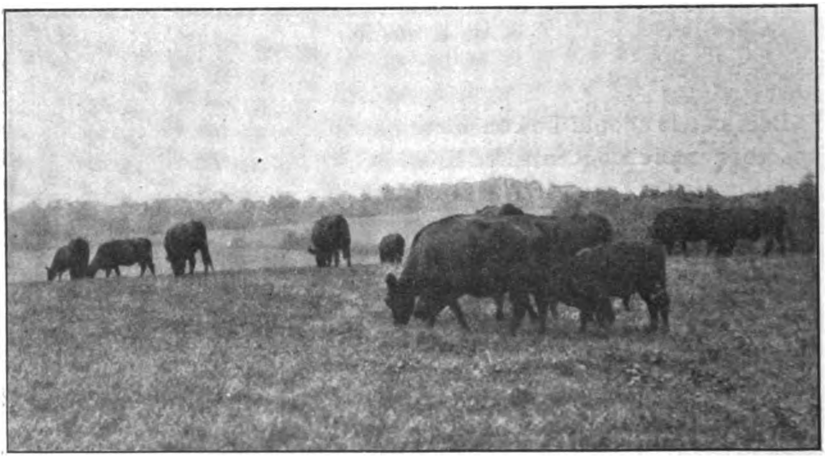

Fig. 1. Aberdeen Angus cows, on College Farm pastures. The profitable production of feeding cattle necessitates the maintenance of herds of cows of beef type.

The demand for feeding steers from farming sections has continually increased, and the area not under cultivation upon which they could be produced with a minimum of expense has decreased to such an extent that the purchase of feeders and the finishing of them for market does not return so great a profit as in former years. The increase in land values has been so rapid in sections which formerly supplied eastern feed lots with steers that the time is approaching when Pennsylvania will produce the major proportion of the cattle fed for market within her borders. The relatively cheap land, favorable soil and climatic conditions, large area of broken land, excellent local demand for good killing cattle, and the necessity for building up the fertility of the soil indicate a revival of the breeding of beef cattle in the state.

The gradual increase in cattle values as based upon Chicago market reports during the past twenty-five years is shown in the following table:

AVERAGE PRICE PER CWT. FOR CATTLE ON CHICAGO MARKET FOR 5-YEAR PERIODS DURING 25 YEARS.

	1886-90	1891-95	1896-1900	1901-5	1906-10
Average price of cattle over 1200 lbs.	$4.34	$4.45	$4.98	$5.53	$6.21
Average price of cattle 900 to 1200 lbs.	3.77	3.81	4.14	4.73	5.40

A careful study of these figures will show that there has not only been an increase during each period of five years, but that each increase has been greater than the preceding one during the same period of time. In other words, the average value of cattle has not been permanently affected by short periods of depression. During the time under consideration, the value of heavy cattle has increased $1.87 per cwt., or 43%, and of light cattle $1.63 per cwt., or 45%. Of this increase, 68c per cwt., or 36%, on heavy cattle, and 67c per cwt., or 41%, on light cattle, has been secured during the last five years. This would seem to indicate that the production of cattle is more profitable than ever before, and that the tendency is to market them at a lighter weight and an earlier age than formerly.

The Place for Beef Cattle in Pennsylvania.

Beef cattle should be found on every farm in the state where cattle are not handled for the exclusive production of milk. Whether or not the farmer enters the dairy business, or handles beef cattle, should depend upon the amount of labor available in proportion to crops produced, the demand for milk and its products, and the equipment for the proper production of milk. Beef cattle will consume a larger amount of feed than any other class of farm animals in proportion to the labor necessary in handling them. They are especially adapted to the utilization of roughage, require a small outlay for buildings and equipment, and return to the soil a very large percentage of the plant food consumed, thus reducing expense of fertilizer. In those sections of the state where the greater percentage of land is too steep to cultivate and is adapted to the production of grass, the growing of feeding cattle should be considered. In sections where all of the land can be cropped continuously from year to year and where there is a large amount of corn and roughage to dispose of, finishing feeders for market should be preferred. Where only a portion of the land is too rough to plow, then the production of "baby" or yearling beef may be advisable. Those who produce feeders or finish yearling beef must of necessity use pure-bred beef bulls with cows having every evidence of beef blood if they expect to avoid loss. Those who finish steers for market may possibly derive as great a profit from finishing steers of inferior breeding and type as from feeding the most approved beef animals, provided the original price paid for inferior individuals is in proportion to their inferiority. Whenever a feeder secures a profit from finishing an inferior steer, it means that the

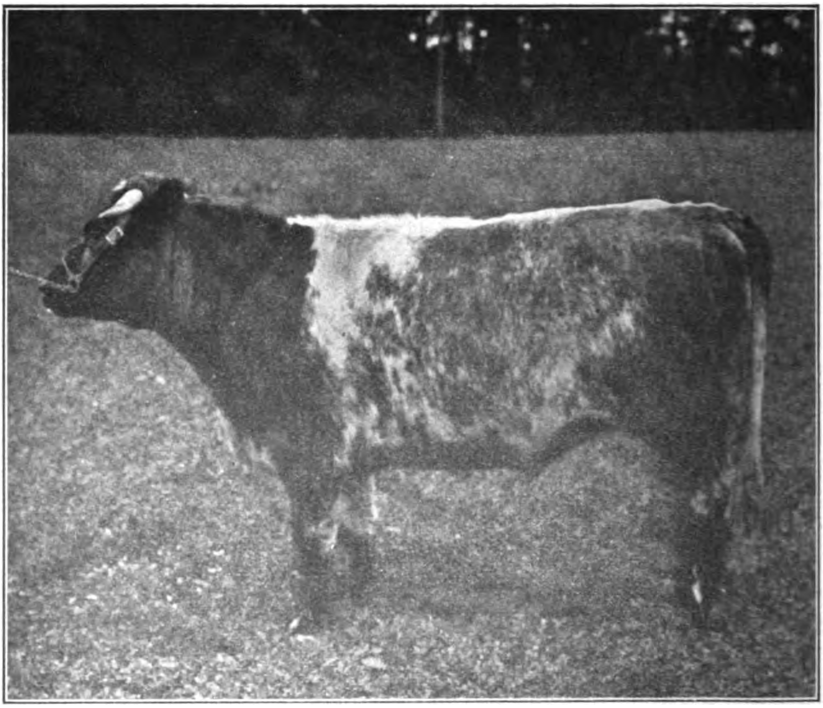

Fig. 2. Pure bred yearling Shorthorn steer. The ideal fat steer yields a large proportion of carcass to waste when slaughtered. The carcass yields a large proportion of valuable cuts in comparison with cheaper parts. This type is profitable to producer, feeder and slaughterer.

producer has marketed the animal at a loss. When steers of the best beef type are purchased and finished, it usually means that they have been profitable from birth to market. The production of steers from dairy and scrub cows is a practice that should be discontinued. Calves from such cows should be marketed as prime veal weighing from 160 to 180 pounds, when their total value will be greater than that of the same animal at 12 months of age in stocker or feeder condition.

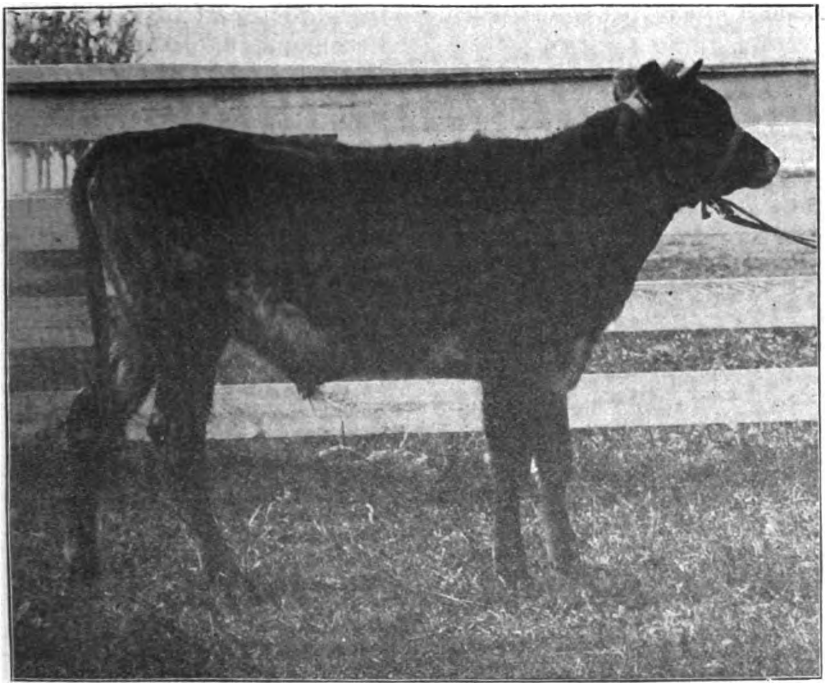

Fig. 3. A yearling "scrub" steer. This type is unprofitable to the producer. If bought at low price, fed for a short period of time, and sold well, inferior cattle may return a profit to the feeder.

In producing beef cattle, the profit depends upon the type, breeding and quality, and selling price of the steers, the value of feeds, the cost of gains and the utilization of the by-products of the feed lot. The profit from purchasing steers and feeding them for market depends upon the margin between purchase and selling prices, the value of feeds, the cost of gains and the utilization of by-products of the feed lot. The producer depends more largely upon the breeding of his cattle; the finisher upon the margin between purchase and selling prices; in other ways, the two systems are quite similar. Pure-bred beef bulls of serviceable age suitable to use for the production of steers may be purchased at prices ranging from $75.00 to $125.00 and upwards per head. The value of a scrub bull of the same age would be from $25.00 to $30.00, or a difference of $50.00 to $100.00, in initial investment. The value of a high-grade beef calf weighing 500 pounds when six months of age is $10.00 greater than that of a scrub of the same weight and greater age. The difference in value of the two bulls will be recovered on the first five to ten calves produced. As a bull may be kept in service for three seasons, only a small number of cows would be required to justify the use of pure-bred sires instead of "scrubs", which are in great majority throughout the state. When the pure-bred bull has outlived his usefulness as a breeding animal, he may be sold for slaughter for as much as, or more than, his original cost, and the owner may have the satisfaction of knowing that his live stock has been improved from year to year.

The Ideal Fat Steer

The ideal fat steer yields a large proportion of carcass to waste when slaughtered. The carcass yields a large proportion of valuable cuts in comparison with cheaper parts. All portions are covered with a smooth layer of white fat. The bundles of muscle fiber are of fine texture and a bright red color, with particles of fat distributed through them, giving the meat a marbled appearance. The bones are dense, hard and small. There are two factors which determine the usefulness of the steer on the block—breeding and feeding. Breeding determines type and general quality. Feeding determines condition, form and the quality of meat. The most profitable steer to the butcher is one that is low-set, blocky, smooth and symmetrical; with short neck; straight, broad back and loin; wide, long and level rump; smooth shoulders; deep ribs; light brisket and paunch; heavy hind-quarters; fine bone; and smooth, even covering of fat over the entire body. The legs should be wide apart and straight; the under line parallel with the top line; the hind flanks deep and well filled with fat.

The Ideal "Feeder" Steer

The ideal feeder differs from the ideal fat steer in condition, which materially affects his form. He should have the same short neck, short legs, straight back, and deep body. He will not be quite so smooth, but there should be an entire absence of coarseness. His neck will be thinner, the back not so broad, the hind flank not so full, the hind quarters not so heavy. The legs should be short and straight, but will not stand so far apart. In selecting a feeder, the head should be short and broad, the muzzle large, the jaw strong, the disposition quiet, the shoulders smooth and compact, the chest wide especially at the bottom, the body deep in front, in order to secure room for the development of vital organs, and deep at hind flank to insure large capacity for handling feed. The muscle of the forearm should be heavy, indicating a thickness of lean meat throughout the carcass, the cannon bones short, indicating early maturity. The loin should be wide, the hook bones far apart, but smooth, and the rump long and wide. The muscles of the thigh should come well down toward the hock. During the finishing period, there will be a marked improvement in the form of the steer, wherever there are heavy muscles because of the deposit of fat between the fibers, and very little improvement where the muscles are light. The neck, back, loin, rump and round will broaden and thicken. Quality will apparently improve because of feeding.

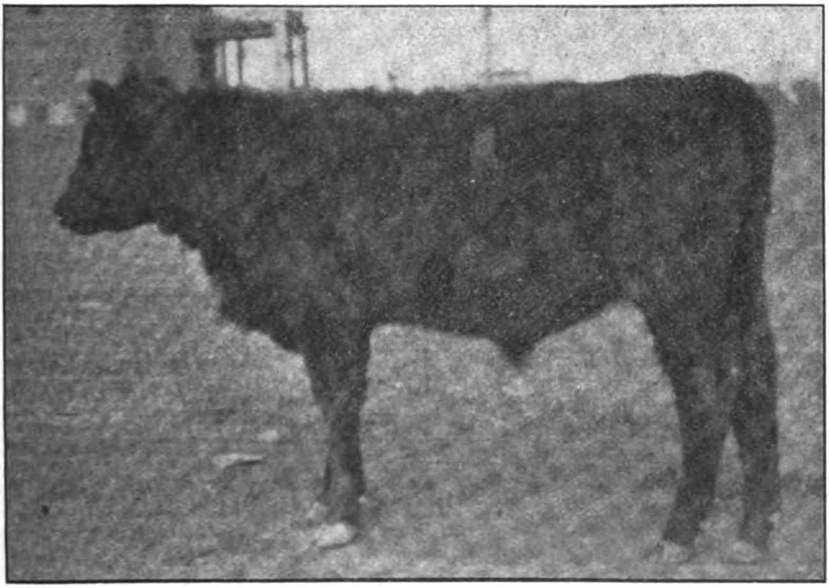

Fig. 4. Aberdeen Angus steer. The feeder steer should be blocky and compact; should have a short, broad head, straight back, deep body and short legs. There should be an absence both of delicacy and of coarseness.

While the handling quality of fat steers is important as an indication of the quality of meat, it is essential in the selection of feeders to secure a loose, pliable, mellow skin, with a heavy, even covering of fine, bright hair, which indicates health, thrift, vigor and the ability to convert feed into meat at relatively small cost.

It is immaterial whether Angus, Galloway, Hereford or Shorthorn bloood predominates, provided feeders of desirable type are secured. The development of each of these breeds has been made with the same purpose in view—to produce early-maturing, thick-fleshed animals with the constitution and capacity to consume large amounts of feed and to convert it into prime beef at low cost. It is advisable to secure all of the steers as nearly uniform in size, type, condition and color as possible, so that when finished they will produce the same grade of beef and may be sold in one lot without any discrimination on the part of the buyer. It is usually more profitable to handle them in carload lots (18-22) in order to save freight, yardage and commissions which are the same on a full load as on three-fourths of a load.

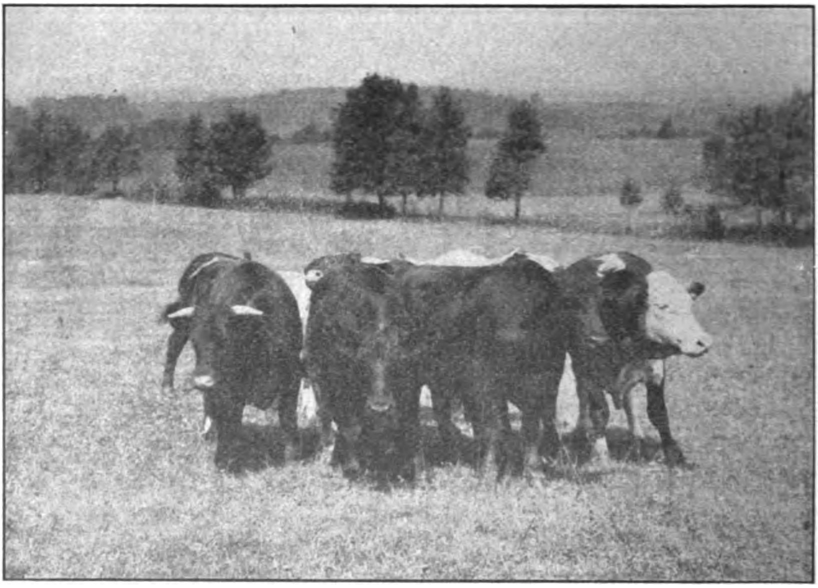

Fig. 5. Representative types of pure-bred Shorthorn, Angus, Galloway and Hereford steers used in instructional work at The Pennsylvania State College.

The Value of Feeders.

The value of feeders is determined by their type, quality, age, condition and weight, the locality, season of year, value of feeds, and probable condition of the fat cattle market when they are finished. The more nearly the feeder steer approaches the type of the ideal fat steer, the greater will be his value per pound. Quality is indicated by refinement and general absence of coarseness. It is associated with early maturity, insures rapid gains in the feed lot and an ability to finish into marketable form in a comparatively short feeding period. Quality also indicates that the steer when finished will dress out a high percentage and yield a smooth, attractive carcass with a maximum proportion of valuable cuts of well marbled beef. It is essential to profitable feeding of young or immature cattle, but may be sacrificed in purchasing older animals, provided the purchase price is sufficiently low. The presence of quality always enhances the selling value of cattle.

The age of feeders has some bearing upon their original cost. If type and quality are sought for, they can be found in calves much more readily than in yearlings or two-year-olds. The younger cattle, when weight, quality, type and condition are similar, will always sell at a higher price than older animals, as they will prove less expensive in the feed lot. Feeder calves of blocky, early-maturing type and with an abundance of quality, taken directly from their dams at a weight of 400 to 500 pounds, will sell higher than at any future time in their lives, unless they are made fat enough to find favor for slaughter. Because of their low initial weight, an increase in price per pound is not so serious as with heavier cattle. An increase of $1.00 per hundred on the initial cost of a 500 pound calf will be balanced by an increase of 50 cents per hundred when the same individual weighs 1,000 pounds. When finished for market, the age of the animal has little influence upon selling price, provided there is no difference in quality, type or condition. It is a much more difficult process and requires a greater length of time to finish calves than to finish mature cattle, a fact which should always be considered when purchasing cattle for feeding purposes.

There are two factors which determine the weight of cattle—their size and their condition. With corn at 60c per bushel, the total cost of fattening two-year-old steers will be approximately $10.00 per hundred. For this season, the higher the condition, or the degree of fatness, of a feeder, the more valuable will he be per pound. Assuming that a steer costing $5.00 per hundred will weigh 1,000 pounds and require 300 pounds at $10.00 per hundred for finishing, he will have to sell at $6.15 per hundred to prevent loss. If, at the same time, another steer weighing 1,100 pounds, the increase being fat rather than mere size, could be finished with a gain of 200 pounds and sold for $6.15 per cwt., it would be possible to pay $5.45 per cwt. for him as a feeder, without loss. The difference in condition of the two steers would be represented by a difference of 45c per hundred in initial value.

It is essential in finishing cattle for market that there be an increase in value per cwt. When cattle are not made excessively fat, a monthly increase in value of 25c to 30c per hundred pounds, based upon weights in feed lot, is sufficient to insure a profit. If heavy steers, similar in age, quality, type and condition, which require the same increase in weight as lighter individuals for finishing, can be purchased at the same price per pound, the profit from feeding them will be greater, as shown by the following comparison:

To steer wt. 1.000 @ $5.00 per cwt.	$50.00
To 350 lbs. gain @ $10.00 per cwt.	35.00
Total cost of steer and feed	$85.00
By steer wt. 1,350 lbs. @ $6.50 per cwt.	$87.75
Profit	$ 2.75
To steer wt. 1,100 lbs. @ $5.00 per cwt.	$55.00
To 350 lbs. gain @ $10.00 per cwt.	35.00
Total cost of steer and feed	$90.00
By steer wt. 1,450 lbs. @ $6.50 per cwt.	$94.25
Profit	$4.25

The additional profit of $1.50 on the 1,100 pound steer is due to the increase in value of $1.50 per hundred on the original 100 pounds excess weight. In order to have obtained the same profit from feeding the 1,000 pound steer, he should have been purchased at $4.85 per hundred or 15c less than the 1,100 pound steer, which was similar in every respect except that of weight.

In the same way the superiority of well-bred cattle in the feed lot may be shown by assuming that the cost of gains on two steers of similar weight is the same and that each of them is fed to the same weight, one of which cost $5.50 per cwt., the other $4.50, the difference in value being due to a difference in breeding. When sold, each steer had improved sufficiently to make him sell $1.25 per cwt. over purchase price.

	High-grade beef steer.	Inferior steer.
Initial weight	1,000 lbs	1,000 lbs.
Initial cost	$55.00	$45.00
Gain in feed lot	300 lbs.	300 lbs.
Cost of gain	$30.00	$30.00
Total cost of finished steer	$85.00	$75.00
Selling value per cwt.	$6.75	$5.75
Total selling value	$87.75	$74.75
	Profit $ 2.75	Loss $ .25

This exhibit indicates that there would be a greater profit in feeding well-bred steers, provided the margin between buying and selling prices, the rate and cost of gains, were the same. It frequently happens, however, that purchasers of feeding cattle are so desirous of securing well-bred feeders and will pay so much for them that the small margin between buying and selling prices eliminates profit, while because of lack of demand for inferior feeders the price is so low that there is a profit derived from finishing them.

Local conditions have a decided influence upon feeder values. In sections where there are large grazing areas with little or no ground producing concentrated feeds for cattle, feeders are much cheaper than in sections where a small proportion of the land is in grass and there is a surplus of corn and other concentrates produced. The large central markets of Chicago, Kansas City, Omaha, Buffalo and Indianapolis determine the value of feeders. Where it is necessary to market a surplus of feeding steers, their home value is determined by market values, less shipping expenses. In Pennsylvania, the value of feeding steers is determined by the Chicago market price with the addition of freight, feed and yardage and a sufficient increase to overcome the shrinkage *en route,* profits from middlemen and probable loss from accident or disease.

Feeding cattle are usually cheaper during the fall months than at any other season, due to the large number of steers received from western ranges and from grazing lands in other sections, and the necessity for feeding and shelter in winter, making the maintenance of herds more expensive. The large supply of grass-fat cows and heifers also decreases the demand for light killing steers at this season. During the late winter and spring months, the supply of butcher cattle, finished on cheap feeds, is entirely eliminated, hence the slaughterers turn to the fleshy feeders for a supply of cheap beef, thus enhancing the value of raw material for the feed lots.

During the late winter or early spring months, there is always a tremendous demand for thin stock cattle to be used for grazing purposes on farms where cattle are not produced. It is frequently advisable to postpone the purchase of thin stock cattle until this demand has subsided, thus allowing pasture grasses to gain in value while cattle values are declining. An excellent time for purchasing feeding cattle is during the months of July and August when the markets are frequently glutted with steers because of large grazing areas suffering from drought.

The supply of grain and roughage throughout the entire country has a decided influence upon the price of feeders. When there is an abundant crop of corn there is usually a strong demand for heavy, fleshy feeders weighing from 1,000 to 1,100 pounds. This is especially true when the supply of roughage has been limited by short hay crops. When early frosts have materially damaged the corn crop there is a demand for feeding cattle far in excess of that which normally occurs when the major portion of the crop matures into marketable condition. When the supply of roughage is abundant and that of grain limited, the demand centers chiefly upon thin stocker steers which may be wintered cheaply and grazed the following summer. When there is an abundance of both concentrates and roughage, the demand for all grades of stockers and feeders is much greater than in years when crops are deficient.

The available supply of feeds has a material effect upon the demand for cattle for slaughtering purposes. With a large crop of corn, cattle are usually made much heavier and fatter before shipment, which results in an over-supply of the better grades of beef and diminishes the supply of cheap killing steers. This condition usually results in greater profits from finishing inferior cattle. When the corn crop is light, fewer cattle are fed, they are marketed early in order to save corn, hence there is a limited supply of the better grade and an excessive supply of cheap cattle, which causes a wide spread between the values of the two classes.

The ability to discriminate closely between the relative value of the various grades of feeding cattle is necessary on the part of the cattle feeder in order that he may confine his purchases to that grade which is best worth the money. He should also consider the character of the ration which he will be compelled to use. If it consists largely of roughage, he should buy thin cattle; if he has an abundance of grain, with little roughage, he should buy heavy, fleshy feeders. When industrial conditions are good and labor regularly employed, the demand for beef is excellent, though any general financial depression is quickly reflected in cattle values.

Methods of Feeding

The character of the ration fed to beef cattle should depend upon the purpose in feeding and the condition or degree of fatness of the steers used. As a general rule the cattle feeder cannot afford to purchase roughage or a large proportion of the grain used. It is generally profitable to buy high-grade nitrogenous concentrates to supplement farm grown feeds. If the cattle are very thin at the beginning of the feeding period, they will make rapid and economical gains on roughage alone, provided the roughage is palatable and nutritious. An excellent ration for such cattle can be made from corn silage and a leguminous forage crop, such as alfalfa, clover or cowpeas. When the steers have fattened sufficiently to be classified as "fleshy butcher steers," a light grain ration should be added and increased as the cattle improve until they are ready for sale. Corn should always be used as the basis of a fattening ration. When the roughage consists of corn stover, timothy, millet, sorghum, or straw, nitrogenous concentrates, such as linseed or cottonseed meal, or gluten feed, should be added to the regular rations at the rate of two to three pounds per 1,000 pounds live weight of animals. When alfalfa, clover or other legumes are used entirely as roughage, the nitrogenous feeds may be profitably reduced one-half or more. In starting cattle on grain, it is advisable to use great care to prevent them from becoming "off-feed." This may be done by feeding at regular times each day, starting with six pounds of concentrates daily per 1,000 pounds live weight, divided into two feeds of equal amounts, and increasing, when the condition of the cattle warrants, at the rate of one-half pound per day until the cattle are cosuming twelve to fourteen pounds of concentrates per 1,000 pounds live weight, after which the increase should only be half as rapid until a full feed has been reached. Fattening cattle should have all of the roughage that they will consume without waste at all times. The grain ration should be limited to what they will consume readily in from one-half to three-quarters of an hour even when a full feed.

The rate of gain will depend largely upon the condition and breeding of the cattle and the character of the ration used. If they are quite thin and well-bred, the gain may be from two to three pounds per head daily, where proper rations are fed. As they fatten, the rate of gain will decrease so that just before they are made prime they will not gain more than one and one-half pounds daily even on the best of rations. The age of the cattle has a material effect on the rate of gain. If fed on heavy rations from birth to maturity, the rate of gain will decrease as the age increases. If, however, cattle are allowed to become thin, the older cattle will fatten more rapidly than calves.

Shelter and Feed Lots

The results of seven years of experimental work at The Pennsylvania State College indicate that an open shed, boarded up closely on three sides and kept well bedded at all times, is more efficient for fattening steers than the basement of a barn. During the winter of 1909-10, the cattle fed in an open shed made more rapid gains, attained a higher finish, sold for 15c per hundred more, and returned 11.6c more for each bushel of corn consumed than similar steers fed in the barn. They also required less labor in feeding, and more straw was used in bedding. Results of previous work show that cattle which are fed in groups of 10 or 12 each, with ample room at mangers and troughs, make more satisfactory gains than similar cattle tied in stanchions. This indicates that the methods which require the least amount of labor are the most satisfactory in the feed lots.

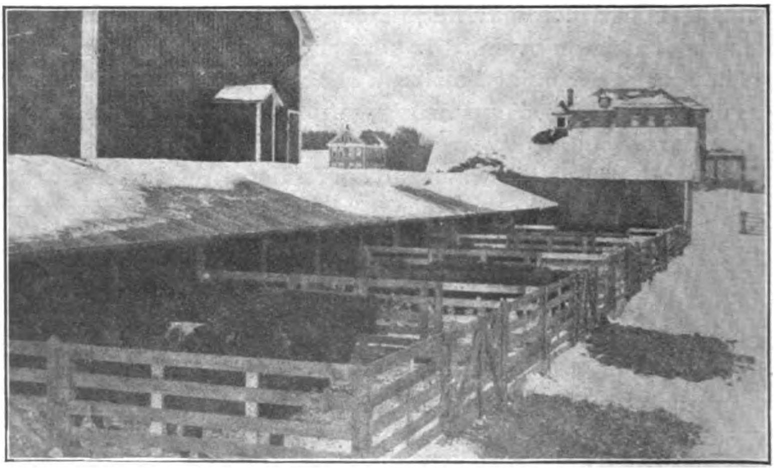

Fig. 7. Experimental steer-feeding shed. Steers fed in an open shed make more rapid gains, attain a higher finish and return a greater profit than similar cattle fed in basement of a barn.

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No 113

EXPERIMENT STATION ABSTRACTS

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
FEBRUARY, 1912

AGRICULTURAL EXPERIMENT STATION
THE PENNSYLVANIA STATE COLLEGE

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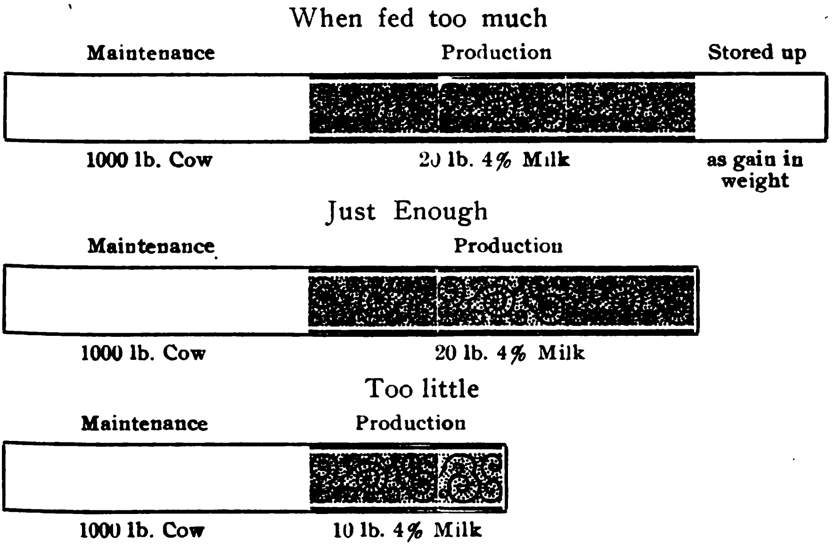
Agricultural Experiment Station

BULLETIN No. 114

A Short Method of
COMPUTING DAIRY RATIONS
According to the Net Energy Standards

By H. E. VAN NORMAN

What Becomes of the Feed Eaten



Feeding experiments show that rations computed according to the net energy standards much more accurately meet the needs of the animal, as determined by the observation and judgment of skillful feeders, than do those computed according to the digestible nutrient standard. The old standard explained the value of feeds in terms of their composition; the new standard explains the values in terms of their power to do work as measured in energy. Energy is measured by the heat created when work is done or food is digested. The two tables which follow will suggest the reason for this statement. In the digestible nutrient standard only one loss, that in the feces, was deducted from the total amount fed, while in the net energy standard four losses are deducted, i. e., in feces, gas, urine, and labor of mastication, digestion, etc., the remainder being the net energy available for milk production and maintenance.

*TABLE I—The Relative Net Energy in Corn Meal, Timothy Hay and Wheat Straw.

Per Cent. of the Total

Total Energy—%	Lost in Feces	Lost in Gas	Lost in Urine	Lost in Labor	Total Loss	Net Energy
100 ℔ Corn Meal	9.2	9.3	3.9	36.3	58.7	41.3
100 ℔ Timothy Hay	48.9	3.8	3.1	29.5	85.3	14.7
100 ℔ Wheat Straw	54.8	9.0	2.5	27.7	94.0	6.0

In this table it is apparent that only 41.3 per cent. of the total energy of corn is available for milk production, that is, as net energy. In timothy hay only 14.7 per cent. of the total energy is net, while in wheat straw only 6 per cent. is net.

The relative feeding values of these feeds expressed in terms of digestible nutrients as compared with their relative value expressed in net energy are shown in the following table:

TABLE II—Relative Per Cent. of Digestible Nutrients and Net Energy in Certain Feeds

	Total Digestible Nutrients	Net Energy
Corn Meal	100.	100.
Timothy Hay	65.	35.5
Wheat Straw	51.9	14.5

Considering the percentage of each in corn meal as 100, when calculated in terms of digestible nutrients timothy hay has 65 per cent. as much total digestible nutrients as corn meal but it has only 35.5 per cent. as much net energy, while wheat straw has 51.9 per cent. as much total nutrients as corn meal but only 14.2 per cent. as much net energy. It is apparent that the net energy of these feeds much more nearly represents their relative feeding values from a practical standpoint than do the total digestible nutrients. The old standards expressed the values of feeds in terms of their composition; the new standard expresses the values in terms of their power to do work as measured in energy. This then is the reason why it seems desirable to accept new standards and new terms for expressing values of feeds and as a basis for computing

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*According to Armsby in Henry's Feeds and Feeding, 11th Ed., p. 50.

rations. The values of feeds in this discussion will be expressed in terms of net energy, the unit of measure being the therm, equal to 1000 calories, one therm being the amount of energy or power required to do work, which when converted into heat, will warm approximately 1000 pounds of water four degrees F.

STANDARD

A cow requires a certain amount of food to keep her alive, without giving any milk, gaining in weight, or growing a foetus; this is called the maintenance ration. Under ordinary conditions the amount of milk which a cow gives is directly in proportion to the amount of feed which she eats **over and above the** maintenance ration **up to the** limit of her inherent **milk-making ability.** If she eats more than this amount she then stores it up in her body in the form of fat to be given off later when her milk-making power calls for more material than her daily ration supplies; if she eats less she either robs her body or lessens her milk yield or both.

To maintain a 1000 pound cow 24 hours 6 therms of net energy are required. If she is to produce 20 pounds of milk, testing 4 per cent., she will require an additional 6 therms of net energy, or a total of 12 therms. If, however, she were to produce only 10 pounds of milk she would require only three therms of net energy above the maintenance ration, or a total of 9 therms. Therefore as stated above, the amount of energy required above maintenance is in proportion to the amount and quality of milk produced.

Without explanation as to the reason for this assertion, it should be borne in mind that every cow must have some protein in her ration. An *insufficient* amount of protein *will limit* the production of milk as surely as an insufficient amount of net energy will limit it. Energy may be derived from the several constituents of the feed; protein, carbohydrates and fat all furnish energy. Milk containing different percentages of fat possesses different amounts of protein and energy.

The following table shows the amount of digestible protein and net energy required per day for maintenance by cows of different weights:

TABLE III—Maintenance Requirement for Cows.

	Pounds Digestible Protein	Therms Net Energy
750 ℔ cow requires for maintenance about	.4	4.95
1000 ℔ cow requires for maintenance about	.5	6.00
1250 ℔ cow requires for maintenance about	.6	7.00
1500 ℔ cow requires for maintenance about	.65	7.90

For any given cow there must be added to this maintenance ration an additional amount for milk production, depending on the quantity of milk produced and its quality. The following table shows the amounts of digestible protein and net energy which must be added to the maintenance ration for the production of different amounts of milk of different qualities:

TABLE IV—Requirements for Milk Production in Addition to Maintenance.

	3 % Milk		4 % Milk		5 % Milk	
	Protein	Energy	Protein	Energy	Protein	Energy
For 1 ℔ milk	.045	.22	.05	.30	.055	.39
For 10 ℔ milk	.450	2.20	.50	3.0	.55	3.9
For 15 ℔ milk	.675	3.30	.75	4.5	.825	5.58
For 20 ℔ milk	.900	4.40	1.00	6.0	1.10	7.8
For 25 ℔ milk	1.125	5.50	1.25	7.5	1.375	9.7
For 30 ℔ milk	1.35	6.60	1.50	9.0	1.65	11.7

It is possible to figure out quite accurately the protein and net energy requirements for a given cow producing a definite amount and quality of milk. So far, the mathematical calculation of a ration is an exact science but feeding as actually practiced with the ordinary commercial herd is not an exact science, and the mathematics must be supplemented by the study, observation and judgment of the feeder. It is not practicable to spend the time necessary under ordinary conditions to figure out an exact ration for each cow according to the standards recommended.

Feeding Practice

It is practicable, however, to make up a mixture of grains and other concentrates and to feed each cow from this grain mixture in proportion to her daily milk yield, and then to give her all the roughage she will eat up clean and be reasonably sure that she has had all the food she needs to produce milk to the limit of her ability under ordinary conditions; hence, the following rules:

1. Feed grain in proportion to milk yield, i. e. give her for example, one pound of grain mixture per day for each three or four pounds of milk produced in one day.
2. Feed all the roughage, which the cow will eat up clean, up to the point where she gains too much in weight.
3. Whenever she becomes too fat, reduce the amount of roughage, leaving the amount of grain to be determined by the milk yield.

When a cow leaves uneaten either grain or roughage, which is free from mould, dirt or foreign material, it should be removed immediately, the manger swept clean, and a much smaller amount given at succeeding feedings until her appetite returns, as evidenced by the cleaning up of her manger; the amounts should then be gradually increased until she is on full feed. It is apparent that the skill of the feeder will be shown by his ability to judge of a cow's appetite for roughage, and to encourage her to eat until the total supply of food consumed fully meets her daily need for maintenance and milk production, as indicated by her gain in weight, i. e. the storage of a surplus in her body as fat.

These suggestions do not imply that grain produces milk and roughage maintains body weight, but it is simply a convenient means of giving that elasticity in feeding practice which is absolutely essential in order to approach a maximum production of milk. For instance a cow producing 20 pounds of milk requires a total of 12 therms of net energy a day. If she is fed one pound of grain for each four pounds of milk, she will require five pounds of grain. If this grain contained four therms of net energy it would leave eight therms of net energy to be supplied by the roughage, and a cow can, and ordinarily will, eat enough hay and silage or hay and corn stover to furnish eight therms of net energy.

TABLE V—Net Energy Required and Supplied by Grain Mixture and Roughage.

Required for maintenance by 1000 lb. cow	6	Therms Net Energy
Required for 20 ℔ milk, testing 4% fat	6	“ “ “
	12	
1 lb. grain for each 4 pounds of milk would require 5 ℔. grain mixture, which would supply	4	“ “ “
Remainder to be supplied by the roughage	8	“ “ “

If, however, she were producing only 10 pounds of milk, she would receive two therms of net energy in grain, and, as she requires only nine therms a day, that would leave seven to be secured from the roughage. It is necessary that the grain mixture contain enough protein so that the protein in the grain mixture and in the roughage will together meet the total requirements of the cow for the day. This reduces the mathematics of the feeding problem to the making of a grain mixture, to be fed in proportion to milk yield, which shall contain enough protein for ordinary requirements.

The proportion of digestible protein to net energy in a grain mixture will be influenced by the character of the roughage to be fed with it, amount of grain to be fed, and to a slight extent, by the amount and quality of the milk which the cow gives.

Roughage—For the purpose of making grain mixtures. all roughage may be put into one or the other of three groups:

Group I includes timothy hay, corn stover and corn silage, or any combination of them. This group requires a narrow grain mixture, such as one pound of protein to four therms of net energy.

Group II includes mixed clover and timothy hay, or combinations of silage or fodder and mixed hay or clover hay, or alfalfa hay when the clover or alfalfa amounts to approximately one-half of the total roughage. This group requires a medium mixture, one pound of protein to five or five and one-half therms of net energy.

Group III includes clover hay or alfalfa hay as the entire roughage. This group requires a wide mixture; one pound of protein to seven therms, or even more, of net energy.

The Amount of Grain

The less grain fed in proportion to the amount of milk produced, the more digestible protein the grain mixture must contain in proportion to its net energy, except when the roughage is all clover or alfalfa. Then the amount of grain fed makes little difference in the ratio of protein to net energy.

The Amount and Quality of the Milk

Except where the roughage is from Group I, the more milk the cow gives the more digestible protein the grain mixture should contain in proportion to net energy. In case the roughage is from Group I, the amount of milk makes little difference. For equal quantities of milk, the smaller the percentage of butter fat the more protein is required. However, the variation in the proportion of protein to net energy on account of the quality of the milk is not nearly as important as the variation due to the character of the roughage. Generally speaking, one should err on the side of more rather than less protein than is needed, because, as a rule, the only objection to a little excess protein is a slight increase in cost, while a deficiency of protein lessens the actual milk yield.

Selection of Grains and Other Concentrates

In selecting concentrates to combine as a grain mixture, the following factors should influence the selection:

Cost, that is, the real price at which each will supply digestible protein and net energy

Effect on the System or Health of the Cow
Palatability
Bulk
Variety

Cost.—It is not the cost price a ton of feeds which determines their relative economy, but the relative cost of net energy and the relative cost of digestible protein in the different feeds. For convenience in computation and comparison, make a list of the available concentrated feeds, i. e., grains and by-product feeds, both home grown and purchasable with their market prices. Divide the *price of 100 pounds* of each feed by the *pounds of digestible protein* in 100 pounds of that feed, multiply this by 100, which will show the relative cost of 100 pounds of digestible protein. Next, divide the price of 100 pounds of the same feed by the *number of therms of net energy* in 100 pounds of this feed and multiply by 100 to show the relative cost of 100 therms of net energy.

In selecting feeds for a grain mixture, use as a basis of the mixture those feeds which furnish net energy at the lowest cost. Then combine with these those which furnish digestible protein at the lowest cost. The final test of economy is a grain mixture which contains the necessary amount of digestible protein and furnishes net energy at the lowest price per 100 therms, and which is at the same time healthful, palatable, bulky, and includes a variety of concentrates. None are ideal when fed alone.

Effect on Health—No mixture should contain an undue amount of feeds that are either constipating or laxative in their effect. Excess of cottonseed meal is constipating while excess of oil meal is the reverse. As a rule, oil meal should not be fed in such amounts as to give more than a half pound to a pound and a half to each cow daily. Cottonseed meal should rarely exceed one-third of the grain feed, and the total amount for the day should not exceed four pounds. Skillful feeders, who are accurate judges of the conditions of their cows, do exceed these limits, but for general practice the amounts stated constitute a safe guide. Cottonseed meal tends to produce a hard, white butter; gluten feed tends to produce a soft butter.

Palatability—Most cows can be taught to eat almost any desirable feed by mixing a small amount of the new feed with that to which they are accustomed and which they like. It is usually better, however, to have the grain mixture contain a reasonable proportion of the feeds which cows relish.

Bulk—It is believed that feeds are more thoroughly digested when they are rather light and bulky, permitting the digestive juices to easily permeate them; that heavy feeds like cornmeal, cottonseed meal or middlings yield to the digestive juices much more slowly. Therefore, a mixture, which in addition to the heavy feeds contains a fair proportion of the light, bulky ones, such as bran, distillers' dried grains or corn and cob meal, is desirable. In the absence of these, the same result may be gotten by chopping hay in the cutting box, dampening it and sprinkling the heavier grain feeds on the wet, cut hay at feeding time.

Variety—A mixture of three or four grain feeds usually makes possible the securing of palatability, variety and desirable physical effect, and it is believed that cows are less apt to become tired of and to refuse to eat a mixture of several feeds than one individual feed.

Amount of Grain to be Fed

If roughage is abundant and grains are high priced and cows are not being forced, one pound of grain to each four pounds of milk produced daily is a good rule. If roughage is high priced and scarce compared with grains, or if it is desirable to push the small cow producing rich milk or the large cow giving a large amount of milk containing a low percentage of butter fat, one pound of grain to each three pounds of milk is a good rule, while the happy medium between these, namely, one pound of grain for each three and one-half pounds of milk is a safe rule under most conditions. If the feeds selected are high in crude fiber and consequently low in net energy, that is, 55 to 65 therms per 100 pounds of the mixture, it may be desirable to feed a little more heavily of grain than if the mixture contains 75 to 80 therms per 100 pounds of mixture.

To Determine the Proportion of Protein to Net Energy

1. Determine to which group the available roughage belongs.
2. Decide the amount of grain to be fed in proportion to milk yield; whether one pound of grain for each three pounds of milk or one pound of grain for each four pounds of milk, etc., should be the proportion.
3. Determine the average yield of milk of each cow in the herd.
4. Determine the average test of the milk.

In the absence of exact knowledge the percentage of fat for the milk of the herd may be assumed to be 4%, or as follows:

All Jerseys or Guernseys or high grades	5%
Mixed herd with some Jersey or Guernsey animals	4.5%
Common mixed herd	4%
Mixed herd with some Holstein animals	3.5%
All Holsteins	3%

With the preceding data in mind and Table VI, the ratio of protein to net energy may be determined.

TABLE VI—Ratio of Digestible Protein to Net Energy for Different Roughages, Qualities and Quantities of Milk.

When roughage is	And feeding one pound of grain for each **four** pounds of milk per day.	Or when feeding one pound of grain for each **three** pounds of milk per day.
GROUP I Consisting of **timothy hay** or **corn silage** or **corn stover** or any two or three of them, make a mixture.	For cows producing **less than 15 lbs.** of milk per day, make a mixture containing protein **1 to 3.5** of net energy; if producing **over 13 lbs.** milk per day make a mixture containing **1 to 4** of net energy.	For cows producing **less than 20 lbs.** of milk per day, make a mixture containing **1 to 4.5** of net energy; if producing **over 20 lbs.** milk per day, make a mixture containing **1 to 5** of net energy.
GROUP II **When in addition to silage or fodder, 5 to 7 lb. of clover or alfalfa are fed, or when mixed hay is half clover.**	For cows producing milk testing **3 to 3.5%** fat Protein **1 to 5** net energy. For cows producing milk testing **3.5 to 4.5%** fat Protein **1 to 5.5** net energy. For cows producing milk testing over **4.5%** fat Protein **1 to 6** net energy.	For cows producing milk testing **3 to 3.5%** fat Protein **1 to 5.5** net energy. For cows producing milk testing **3.5 to 4.5%** fat Protein **1 to 6** net energy. For cows producing milk testing over **4.5%** fat Protein **1 to 6.5** net energy.
GROUP III **When all the roughage is clover or alfafa hay**	For cows producing milk testing **3 to 3.5%** fat Protein **1 to 6** net energy. For cows producing milk testing **3.5 to 4.5%** fat Protein **1 to 6.5** net energy. For cows producing milk testing over **4.5%** fat Protein **1 to 8** net energy.	For cows producing milk testing **3 to 3.5%** fat Protein **1 to 6** net energy. For cows producing milk testing **3.5 to 4.5%** fat Protein **1 to 7** net energy. For cows producing milk testing over **4.5%** fat Protein **1 to 8.5** net energy.

In the absence of roots or silage, it is well to include a little oil meal in the mixture.

Let it be supposed that the feeder has timothy hay and silage (Group I, column 1), and wants to feed a pound of grain mixture for each three pounds of milk, (column 3). If the cows are producing about 21 pounds of milk each daily, testing 4%, a grain mixture containing one pound of protein to five therms of net energy would be required.

Convenience Table

For the purpose of compounding grain mixtures, the following table of digestible protein and net energy in each of several amounts of the ordinary feeds has been compiled. The decimal fractions have been omitted so as to lessen the labor of computing. It will be found sufficiently accurate for calculating mixtures, but for computing an exact ration for a single cow use Table VIII on page 20. By using even hundreds of pounds of the different feeds in so far as possible, or multiples of 25 and 50 pounds, labor in computing is saved.

It will be convenient to insert in the proper columns in Table VII the cost price of those feeds which are available to the reader. Then compute the value of digestible protein and net energy at those prices, as indicated in the paragraph under "Selection of Feeds," Cost, page 9.

TABLE VII—Convenience Table for Computing Grain Mixtures.

(For exact composition use Table page 20).

Ratio of Digestible Protein to Net Energy. 1 to			DIGESTIBLE PROTEIN AND NET ENERGY IN					COST OF PROTEIN AND NET ENERGY			
			25 lbs.	50 lbs.	100 lbs.	200 lbs.	300 lbs.	Price per Ton	Price 100 lbs.	Cost 100 lbs Pro.	Cost 100 t Energy
3.6	Ajax flakes	P	5.5	11.	22.	44.	66.				
		E	20.	40.	79.	158.	237.				
10.1	Barley	P	2.	4.	8.	17.	25.				
		E	20.	40.	81.	161.	242.				
3.2	Brewers grs dry	P	5.	9.5	19.	38.	57.				
		E	15.	30.	60.	120.	180.				
3.8	Brewers grs. wet	P	1.	2.	4.	8.	11.				
		E	3.7	7.5	15.	30.	44.				
8.6	Beet pulp (dried)	P	1.7	3.5	7.	14.	20.				
		E	15.	30.	60.	120.	180.				
3.5	Buckwheat mid.	P	5.5	11.	22.	45.	67.				
		E	19.	38.	76.	152.	228.				
12.7	Corn	P	1.7	3.5	7.	14.	20.				
		E	22.	44.	88.	176.	264.				
18.0	Corn and cob meal	P	1.	2.	4.	9.	13.				
		E	18.	36.	72.	144.	216.				
6.0	Corn hearts	P	3.5	7.	14.	28.	43.				
		E	21.	42.	84.	168.	252.				
2.4	Cottonseed meal	P	9.	17.5	35.	70.	105.				
		E	21.	42.	84.	168.	253.				
3.6	Distillers' grains C.	P	5.5	11.	22.	44.	66.				
		E	20.	40.	79.	158.	237.				
6.1	Distillers' grains R.	P	2.5	5.	10.	21.	31.				
		E	15.	30.	61.	122.	183.				
4.0	Gluten feed	P	5.	10.	20.	40.	60.				
		E	19.	39.	79.	158.	237.				
2.4	Gluten meal. Chi.	P	8.	16.5	33.	66.	99.				
		E	20.	39.	78.	157.	235.				

Table VII—Continued

			25 lbs.	50 lbs.	100 lbs.	200 lbs.	300 lbs.	Price per Ton	Price 100 lbs.	Cost 100 lbs. Pro.	Cost 100 t. Energy
12.0	Hominy	P	2.	3.5	7.	14.	21.				
		E	21.	42.	84.	168.	252.				
2.9	Linseed meal o. p.	P	7.	14.	27.	55.	83.				
		E	20.	39.	79.	158.	237.				
2.6	Linseed meal n. p.	P	7.	15.	29.	58.	88.				
		E	19.	37.	75.	149.	224.				
3.8	Malt sprouts	P	3.	6.	12.	25.	37.				
		E	11.5	23.	46.	93.	139.				
8.3	Oats, ground	P	2.	4.	8.	17.	25.				
		E	16.5	33.	66.	132.	199.				
4.2	Pea meal	P	4.	8.	17.	33.	50.				
		E	18.	36.	72.	143.	215.				
10.2	Rye	P	2.	4.	8.	16.	24.				
		E	20.	41.	82.	163.	245.				
5.2	Rye bran	P	3.	6.	11.	23.	34.				
		E	14.	28.	57.	113.	170.				
11.5	Sucrene	P	1.5	3.	6.	12.	18.				
		E	14.	29.	57.	115.	173.				
3.8	Unicorn (est.)	P	5.	10.	20.	40.	60.				
		E	19.	38.	76.	152.	228.				
3.9	Union grains (est.)	P	4.	9.	18.	35.	53.				
		E	18.	36.	71.	143.	214.				
9.2	Wheat	P	2.	4.	9.	18.	27.				
		E	21.	41.	83.	165.	248.				
4.8	Wheat bran	P	2.	5.	10.	20.	31.				
		E	12.	24.	48.	96.	145.				
6.0	Wheat middlings	P	3.	6.	13.	25.	38.				
		E	19.	39.	78.	155.	233.				

Having determined from the preceding table the ratio of protein to the net energy, which for this sample will be 1 :5, that is, one pound of digestible protein to five therms of net energy, and having the following feeds, arrange them one below the other in the form of a list, thus:

Corn meal	Cheapest source of net energy
Cottonseed meal	Cheapest source of protein
Distillers dried grains	Light and bulky, moderate cost of protein
Gluten feed	Adds variety, and protein at moderate cost

For the trial, take that amount, in even hundreds of pounds, which you think will make the desired ratio, then from Table VII obtain the amount of protein and net energy contained in the amount of that particular feed which you purpose to put into the mixture. In column 2, run down the list to corn (same as corn meal) and across to column 7, under 300 pounds, where opposite the letter P is shown 20, this being the number of pounds of protein in 300 pounds of corn. Write this on your paper opposite the 300 pounds of corn meal and under the head "Protein." Opposite the letter E and in column 7, immediately under the amount of protein, is 264, the amount of net energy in 300 pounds of corn meal, which amount write under the heading "Net Energy" on your paper.

Similarly, in column 2, find cottonseed meal. In Column 5, under 100 pounds and opposite the cottonseed meal, is the amount of protein and of net energy in 100 pounds. Copy this on your paper, and in the same way obtain the amount of protein and net energy in the distillers' grains and in the gluten feed. The following example will serve to show the method of obtaining the ratio:

	Pounds Protein	Therms Net Energy
300 ℔ Corn meal	20.	264.
100 ℔ Cottonseed meal	35.	84.
300 ℔ Distillers' dried grains	66.	237.
100 ℔ Gluten feed	20.	79.
	141.	664.

664 ÷ 141 = 4.7, or the ratio of net energy to protein.

The total amount of net energy divided by the total amount of protein results in 4.7 as much net energy as protein in the whole mixture. Since we desire a ratio of 1 :5, this result indicates that we have more protein than we need. This can be reduced by taking out some of the high protein feeds, such as cottonseed meal, distillers' grains or gluten feed, or may be overcome by adding more low protein feed, such as corn meal. For example, add 100 pounds of corn meal to the mixture, adding the protein and the net energy to the above totals as follows:

	Protein	Net Energy
Total from above	141.	664.
100 ℔ corn meal	7.	89.
Total	148.	753.

753 ÷ 148 = 5.0.

Dividing the net energy by the protein, we have a very small fraction more than five times as much net energy as protein, which is sufficiently accurate for the purpose of ordinary feeding.

Now to determine the economy of this mixture before we added the last amount of corn, enter the cost of the four feeds as follows:

300 lb Corn meal	$4.29
100 " Cottonseed meal	1.57
300 " Distillers' grain	4.56
100 " Gluten feed	1.52
800 "	$11.94

Divide the total cost of the mixture, $11.94, by the amount of net energy, 664 therms, as follows:

11.94 ÷ 664 = .01798 × 100 = $1.80, cost of 100 therms.

According to this computation 100 therms of net energy in this mixture will cost $1.80.

But our final mixture contains 400 pounds of corn meal, so that our final mixture costs $13.37 and contains 753 therms of net energy, as follows:

800 lb. (total from above) containing	664 therms cost	$11.94
100 lb. corn meal added	89 therms costs	1.43
900 "	753	$13.37

13.37 ÷ 753 = .0177 × 100 = $1.78.

The final mixture furnishes us net energy at a cost of $1.78 per hundred. The additional corn meal has not only widened the mixture but reduced the cost of net energy, because corn furnishes net energy at present market prices cheaper than any of the other feeds.

A convenient arrangement of the figures would be as follows:

Mixture No. 204.

400 lb. Corn meal	28.	352.	$5.72
100 lb. Cottonseed meal	35.	84.	1.57
300 lb. Distillers' dried grains	66.	237.	4.56
100 lb. Gluten feed	20.	79.	1.50
900 lb. Contains	149.	753.	$13.37
1 lb. Contains	.165	.83	
Protein to net energy	1 :5		
100 therms net energy cost			$1.78

One may check up and determine whether or not the preceding plan of computing grain mixtures and feeding them is meeting the requirements of a particular cow or cows by determining how much protein and net energy a cow of specified size, producing a definite yield of milk, should receive according to the standards. Then, by weighing not only the grain but the roughage actually eaten, determine whether the amounts of protein and net energy consumed meet the standards indicated. If not, such changes in the practice as are necessary to give the required amount should be made. The following illustrates this point:

	Protein	Net Energy
A cow weighing 1000 lb. requires	.5	6.
To produce 20 ℔ of milk testing 4% requires	1.0	6.
Total required per day	1.5	12.

This would indicate that the entire day's ration should contain one and one-half pounds of protein and 12 therms of net energy. If this cow is being fed grain at the rate of one pound to three of milk produced she would require practically seven pounds of grain per day, and she should eat 30 pounds of silage and 10 pounds of timothy hay.

	Protein	Net Energy
7 lb. mixture No. 199 contains	1.078	5.348
30 lb. silage contains	.3	5.3
10 lb. timothy hay contains	.2	3.
	1.578	13.648

If the cow is fed 30 pounds of silage and ten pounds of timothy hay and seven pounds of mixture No. 199, she would have enough protein and net energy to meet the theoretical requirements.

While this plan of feeding suggests that rules can be followed blindly with reasonably satisfactory results, it will not take the place of the skill and judgment of the feeder. Grain feeds and roughage all differ in their composition from one season to another and from different farms, even from different fields. Again, from the same field, they differ, whether harvested early or late in the season. Because of these variations in the feeds and the individual peculiarities of the cow, there will always be room for the feeder's judgment. This may be exercised by the feeding of more or less grain than herein suggested; the addition or omission of some feed to the mixture, with a careful study of the individual animals to see whether or not there is improvement in the yield or in condition, or the reverse, or whether an economy has been effected without loss in the yield. If droppings are too hard, add silage, roots, wet beet pulp or oil meal; if too soft, decrease these and increase hay and dry fodder.

It should always be borne in mind that the cow is not fed for today only; she must be kept in condition to develop a calf and to undergo the changes of season, and the young cow must complete her own growth.

While the plan herein suggested may be a great help to the man who knows little or nothing of the theory of the computation of rations, once he has learned these theories his next step should be the development of his own judgment as a student of his cows to the point where he knows from the appearance of the cows, from the appearance of their droppings, and from the milk yield whether they are doing the best they are capable of doing or what the effect of a proposed change is likely to be or what it has been from actual experience.

The Exact Calculation of a Ration

When it is desirable to compute a ration for a particular cow, it will more nearly conform to the theoretical standards if Table VIII on page 20 is used, because computation is carried out there to the second decimal place, whereas in the convenience table preceding the decimals have been dropped. These make little difference in a mixture of eight or nine hundred pounds, but on a small amount such as one day's feed for one cow, they may materially change the ratio.

Persons desiring to understand more fully the scientific aspects of this question should study Bulletin No. 111 of this Station on "The Maintenance Ration of Cattle" by Dr. H. P. Armsby, Director of the Institute of Animal Nutrition; also Farmers' Bulletin 346, U. S. Department of Agriculture.

Practice

In ordinary practice, the grain mixture may be prepared on the barn or feed room floor, emptying first the light, bulky feeds, such as corn and cob meal or distillers' grains, spreading these out five or six inches thick, pouring on the next lightest, etc. Then begin at one edge, shovel the feed back into a pile a couple of feet to the right or left. Under ordinary conditions, twice turning over and the final shoveling into the bin will afford a uniform mixing.

Where the amounts of grain used in computing a mixture make a larger quantity than is desirable, the use of a half, a fourth or a tenth of each of the feds in the mixture will not change the proportion of protein to net energy. For instance in mixture No. 194

20 ℔ Bran,
10 ℔ Corn meal,
10 ℔ Linseed meal,
10 ℔ Cottonseed meal,

would give exactly the same result as mixing the whole amount; or if you wanted to feed one cow

2 ℔ Bran,
1 ℔ Corn meal,
1 ℔ Linseed meal,
1 ℔ Cottonseed meal,

the ratio of protein to net energy would be just the same as though the whole quantity were prepared and she were fed five pounds of it.

The following are some sample mixtures with the amount of protein and net energy in each. To determine the cheapest, get the total cost of the mixture, divide it by the amount of net energy, and multiply by 100; the result will be the cost of 100 therms of net energy.

1 to 4 Mixtures

No. 194

		Protein	Therms Energy
200lb.	Bran	20.	96.
100lb.	Corn meal	7.	89.
125lb.	Linseed meal, O. P.	34.	99.
100lb.	Cottonseed meal	35.	84.
525lb.	Contains	96.	368.
1lb.	"	.182	.700

No. 196

		Protein	Therms Energy
175lb.	Corn & cob meal	7.	126.
100lb.	Cottonseed meal	35.	84.
100lb.	Distillers' grains C	22.	79.
100lb.	Linseed meal	29.	75.
475lb.	Contains	93.	364.
1lb.	"	.195	.766

No. 107

		Protein	Therms Energy
200lb.	Corn and cob meal	9.	144.
150lb.	Cottonseed meal	52.5	126.
175lb.	Distillers' grains C	38.5	139.
100lb.	Gluten feed	20.	79.
625lb.	Contains	120.0	488.
1lb.	"	.192	.780

No. 198

		Protein	Therms Energy
100lb.	Corn meal	7.	89.
300lb.	Linseed meal, (O. P.)	88.	224.
100lb.	Oats	8.	66.
400lb.	Bran	40.	192.
900lb.	Contains	143.	571.
1lb.	"	.16	.634

1 to 5 Mixtures

No. 195

		Protein	Therms Energy
200lb.	Bran	20.	96.
300lb.	Corn meal	20.	266.
100lb.	Linseed meal	29.	75.
100lb.	Cottonseed meal	35.	84.
700lb.	Contains	104.	521.
1lb.	"	.148	.752

No. 197

		Protein	Therms Energy
450lb.	Corn & cob meal	20.	324.
100lb.	Cottonseed meal	35.	84.
200lb.	Distillers' grains C	44.	158.
100lb.	Linseed meal	29.	75.
850lb.	Contains	128.	641.
1lb.	"	.150	.754

No. 199

		Protein	Therms Energy
400lb.	Corn & cob meal	18.	288.
100lb.	Cottonseed meal	35.	84.
300lb.	Distillers' grains C	66.	237.
100lb.	Gluten feed	20.	79.
900lb.	Contains	139.	688.
1lb.	"	.154	.764

No. 201

		Protein	Therms Energy
300lb.	Corn meal	20.	266.
300lb.	Linseed meal	88.	224.
200lb.	Oats	17.	132.
400lb.	Bran	40.	192.
1200lb.	Contains	165.	814.
1lb.	"	.137	.678

In numbers 196 and 197 use corn and cob meal in place of corn meal and distillers' grains in place of bran.

In numbers 107 and 199 use gluten feed in place of linseed meal.

Numbers 198 and 201 are good mixtures from the feeder's standpoint but too expensive at present prices.

A little linseed meal is desirable in the mixture when neither silage, roots nor wet beet pulp are available.

Selecting Feeds

Bear in mind the following characteristics of each:

ALFALFA MEAL, more convenient to handle than hay, much easier to adulterate, price usually excessive, rich in protein.

BEET PULP, soaked up, a good substitute for silage or roots but higher in price.

BRAN, (wheat) light, bulky, appetizing, high in mineral matter, high in crude fiber. Relatively expensive at present prices.

BREWERS' GRAINS, rich in protein, very variable in composition, bulky, must be fed with other feeds.

BUCKWHEAT, low in protein—usually pays to sell it and buy back the middlings.

BUCKWHEAT MIDDLINGS, heavy, usually economical source of protein, tend to make soft, oily butter.

BULKY FEED, bran, gluten feed, ajax flakes, distillers' grains, corn and cob meal.

CONSTIPATING, cottonseed meal, corn fodder and hay.

CORN, easily digested usually cheapest source of energy. Pays to grind.

CORN AND COB MEAL, bulky, considerable crude fiber, nearly equal to corn meal in ration because of bulky nature. Ground fine.

COTTONSEED MEAL, high in protein, heavy, should be fed with something else, makes for hard butter, relatively cheap source of protein, ordinarily should not constitute more than one-third of the mixture.

DISTILLERS' DRIED GRAINS, mostly corn, light, bulky, high in protein, not readily eaten alone.

DISTILLERS' DRIED GRAINS, mostly rye, similar in character to the corn grains, lower in digestible protein.

GLUTEN FEED, rich in protein, should be fed with other grains, usually a desirable and economical source of protein.

GLUTEN MEAL.

HOMINY CHOP, usually economical source of energy, low in protein, palatable, heavy. Good substitute for corn meal if needed.

LAXATIVE, oil meal, bran slightly, silage, roots.

MALT SPROUTS.

MOLASSES, a non protein feed, good appetizer, usually too high in price for its food value.

MOLASSES FEEDS, usually high in waste materials and too high in price for their feed value.

NOT PALATABLE, gluten feed, brewers' and distillers' grains, cottonseed meal.

OATS, good feed, rich in mineral matter, high in crude fiber, not high enough in protein to use for balancing a ration, too expensive to feed at the past year's prices, good for calves, especially so if ground and hulls sifted out.

PROPRIETARY FEEDS, usually variable in composition, frequently contain weed seed and useless waste material, high in fiber and relatively expensive for the amount of energy furnished, save labor of mixing.

ROOTS, desirable substitute for silage, usually costs more to grow.

SILAGE, succulent, appetizing, economical, low in protein, should be fed after milking, a little hay or dry fodder should always be fed with it. One of the best farm grown feeds for milk products.

TABLE VIII—For the Exact Calculation of Individual Rations

Dry matter, digestible protein, and energy values per 100 pounds.

Feeding stuff.	Total dry matter.	Digestible true protein.	Energy value.
Green fodder and silage:	*Pounds.*	*Pounds.*	*Therms.*
Alfalfa	28.2	2.50	12.45
Clover—crimson	19.1	2.19	11.30
Clover—red	29.2	2.21	16.17
Corn fodder—green	20.7	.41	12.44
Corn silage	25.6	0.88	16.56
Hungarian grass	28.9	1.33	14.76
Rape	14.3	2.16	11.43
Rye	23.4	1.44	11.63
Timothy	38.4	1.04	19.08
Hay and dry coarse fodders:			
Alfalfa hay	91.6	6.93	34.41
Clover hay—red	84.7	5.41	34.74
Corn forage, field cured	57.8	2.13	30.53
Corn stover	59.5	1.80	26.53
Cowpea hay	89.3	8.57	40.76
Hungarian hay	92.3	3.00	44.03
Oat hay	84.0	2.59	26.97
Soy bean hay	88.7	7.68	38.65
Timothy hay	86.8	2.05	33.56
Straws:			
Oat straw	90.8	1.09	21.21
Rye straw	92.9	.63	20.87
Wheat straw	90.4	.37	16.56
Roots and tubers:			
Carrots	11.4	.37	7.82
Mangelwurzels	9.1	.14	4.62
Potatoes	21.1	.45	18.05
Rutabagas	11.4	.38	8.00
Turnips	9.4	.22	5.74
Grains:			
Barley	89.1	8.37	80.75
Corn	89.1	6.79	88.84
Corn-and-cob meal	84.9	4.53	72.05
Oats	89.0	8.36	66.27
Pea meal	89.5	16.77	71.75
Rye	88.4	8.12	81.72
Wheat	89.5	8.90	82.63
By-products:			
Brewers' grains—dried	92.0	19.04	60.01
Brewers' grains—wet	24.3	3.81	14.82
Buckwheat middlings	88.2	22.34	75.92
Cottonseed meal	91.8	35.15	84.20
Distillers' grains—dried—			
Principally corn	93.0	21.93	79.23
Principally rye	93.2	10.38	60.93
Gluten feed—dry	91.9	19.95	79.32
†Gluten meal—Buffalo	91.8	21.56	88.80
Gluten meal—Chicago	90.5	33.09	78.49
Linseed meal—old process	90.8	27.54	78.92
Linseed meal—new process	90.1	29.26	74.67
Malt sprouts	89.8	12.36	46.33
Rye bran	88.2	11.35	56.65
Sugar-beet pulp—fresh	10.1	.63	7.77
Sugar-beet pulp—dried	93.6	6.80	60.10
Wheat bran	88.1	10.21	48.23
Wheat middlings (Flour)	84.0	12.79	77.65

William Bullock

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The Pennsylvania State College Agricultural Experiment Station

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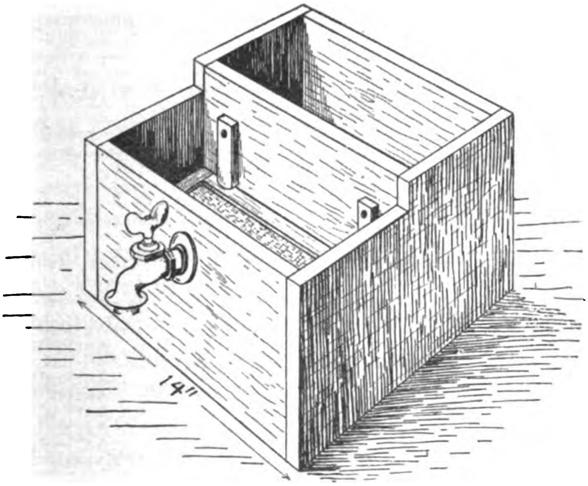
BULLETIN No. 115



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* Absent on leave.

**Died Jan. 19, 1912.

Sun Ptg. & Bdg. Co., Williamsport, Pa.

The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 116

CORN GROWING IN THE EAST

BY THOMAS F. HUNT

The East is adapted to the raising of trees and grass. Those agricultural industries which are based upon trees and grass must be the ones which will flourish in this region as soon as the United States and Canada have ceased to be pioneer countries. Forestry, fruit growing and the rearing, rather than the fattening, of cattle and sheep, are the industries which are based upon the culture of trees and grass. The eastern portion of the United States is devoted to dairying primarily because it contains the great centers of population. The production of butter and cheese has moved westward rapidly because of the abundance of cheap grains.

There is no area in the United States better adapted to the production of grass than the eastern part, but for a century it has lacked cattle. The tide has now turned; western lands are no longer uncapitalized; pioneer farming has in a large degree forever disappeared in the United States. The East is rapidly coming into its own.

Corollary to the fact that the East is adapted to the production of trees and grass is the fact that the East raises relatively large amounts of roughage or bulky foods and relatively small amounts of concentrates or grains. The nine North Atlantic States, i. e., the New England States, New York, New Jersey and Pennsylvania, produced in 1910 four times as many acres of hay as corn, while the North Central States west of the Mississippi River produced more than three times as many acres of corn as of hay. The ratio of hay to corn is, therefore, twelve times as great in the East as in the North Central States mentioned. In other words, while these North Central States produce an excess of concentrates, the eastern states produce an excess of roughage. The following table suggests the extent of these relationships:

Relative Production of Hay and Cereals.

Acres in 1910.

Total Land Area	Nine North Atlantic States	Seven North Central States
Hay	12,573,000	11,198,000
Corn	2,795,000	38,773,000
Total cereals	8,981,000	84,848,000

It is of the greatest importance that the bearing which this circumstance has upon agricultural practice should be understood. Broadly speaking, the food value of any substance depends upon its palatability, and upon the percentage of digestible protein and of total energy which a particular animal may recover in useful work. Without going into details, it may be stated that the percentage of the total energy derived from a specific food by a given animal will depend upon the percentage of food digested and the work of digesting it. Armsby has computed that when Indian corn is fed to ruminants, 46% of the total energy of it is lost, while 74% of the total energy of mixed hay and 94% of the total energy of wheat straw are lost in the process of digestion. The total net energy of these three products stands as follows: 54-26-6.

The energy value may be stated also in heat units per pound. A German authority has computed the energy values as 32.7 therms for average meadow hay, and 126.3 therms to one hundred pounds for Indian corn, when fed to horses. Assuming that a ration contains a proper supply of digestible protein, this method of statement is the most nearly accurate expression that has yet been determined of the relative feeding values of different food products.

The bearing which these facts have upon corn-growing in the East may be shown by referring to the series of fertilizer experiments that has been made at the Pennsylvania Station. During the past thirty years, a series of four tiers of thirty-six plats each has been in a rotation consisting of corn, oats, wheat and clover, and timothy. Inasmuchas all four crops have been grown every year, it is possible to make a comparison of the relative yield and value of the four crops when grown under identical climatic and soil conditions in the eastern part of the United States. It should be explained further that in this rotation the fertilizer and other soil amendments were applied to the corn and wheat, that is, on alternate years. No fertilizers were applied to the oats or grass.

The following table gives, in some detail, the results during the first twenty-five years of the experiment. The digestible protein and the energy value have been computed from coefficients published in Bulletin No. 111 of the Pennsylvania Experiment Station on "The Maintenance Ration of Cattle," by Doctor H. P. Armsby.

The Average Annual Yield During Twenty-five Years of 24 Treatments on 36 Plats on Each of Four Tiers at the Pennsylvania Station

	Average Yield per Acre		Price per 100 Pounds	Farm Value per Acre	Digestible Protein Pounds	Energy Value Therms per Acre
	Pounds	Bushels				
Corn, ears	3534	50.5	$ .75	$26.51	160	2582
Corn, stover	2528	....	.125	3.16	40	671
Oats, grain	1227	38.1	1.00	12.27	102	813
Oats, straw	1772	....	.125	2.22	19	370
Wheat, grain ...	1192	19.9	1.33	15.85	106	985
Wheat, straw ...	2099	....	.125	2.62	8	348
Hay, Timothy and Clover	3609		.50	18.05	135	1232

These figures may be condensed into a table that will bring out the comparison in a more striking manner, as shown below.

Comparison of Digestible Protein, Energy Value and Farm Value per Acre of Four Crops When Grown in Rotation During Twenty-five Years (1882-1896).

	Digestible Protein—Pounds	Energy Value Therms	Farm Value
Corn	206	3253	$29.67
Oats	121	1189	14.49
Wheat	114	1333	18.47
Hay	135	1232	18.50

The importance of corn in eastern agriculture is plainly emphasized whether considered from the standpoint of digestible protein, energy value, or money value. It would seem probable that Indian corn has not yet reached its limit in price compared with the other three crops. Its energy value is approximately three times as great, while its farm value per acre has been only about twice that of the other crops. The above table also explains why land, which is especially adapted to Indian corn, is high in price.

It does not follow from what has been said that the individual will find it more economical to attempt to raise a large proportion of his concentrates. It may be more profitable for him to buy his corn from his western neighbors, so long as they are willing to allow the fertiilty of their farms to be transferred at a reasonable price to those of their eastern neighbors. Whatever may be best in individual cases, it cannot be doubted from what has just been shown that the prosperity of the East as a whole would be greatly increased if the rotation of crops were so modified as to increase the corn acreage. The following table shows the acres of the several crops grown in the North Atlantic States, grouped into intertilled crops, spring grain, winter grain and hay.

Relative Proportion of Crops in North Atlantic States.

Corn and potatoes	3,895,000	
Oats, barley and buckwheat	3,413,000	
Wheat and rye	2,773,000	10,081,000
Hay		12,573,000
Total acreage in cultivated crops		22,654,000

A careful consideration of this table will show that the composite eastern farmer has a seven-years' rotation in which an intertilled crop, a spring grain, and a winter grain each occupy one year, while hay occupies four years. This is made apparent from the following outline:

Table Showing how Relative Proportions of Crops may be Modified by Length of Rotation.

Acres in Millions.

Crop	Seven Years	Six Years	Five Years	Four Years	Three Years
Intertilled crop	3.2	3.75	4.5	5.6	7.5
Spring grain	3.2	3.75	4.5	5.6	7.5
Winter grain	3.2	3.75	4.5	5.6	7.5
Clover and timothy	3.2	3.75	4.5	5.6	7.5
Timothy	3.2	3.75	4.5		
Timothy	3.2	3.75			
Timothy	3.2				
Total	22.4	22.5	22.5	22.4	22.5

The table above shows how the proportion of Indian corn could be increased by decreasing the length of the rotation. It is quite easy, however, to change the proportion of corn without changing the length of the rotation, as is shown in the following table:

Method of Modifying a Seven-years' Rotation so as to Increase the Proportion of Indian Corn.

Indian corn	Indian corn	Indian corn	Indian corn
Spring grain	Indian corn	Indian corn	Spring or winter grain
Winter grain	Spring grain	Spring or winter grain	Clover
Clover & Timothy	Winter grain	Clover & Timothy	Indian corn
Timothy	Clover & Timothy	Timothy	Spring or winter grain
Timothy	Timothy	Timothy	Clover & Timothy
Timothy	Timothy	Timothy	Timothy

Whether corn should be raised on eastern farms two years in succession will depend largely upon the method of fertilization. As a guide to those who wish to increase their production of this valuable crop, the following outline is given, showing how a three-year, a four-year, a five-year and a seven-year rotation may be fertilized:

Table Showing Method of Fertilizing Crop Rotations.

3 yr	4 yr	5 yr	7 yr	
			1	Corn: 6 to 10 loads of manure and 25 pounds of phosphoric acid.
1	1	1	2	Corn: 6 to 10 loads of manure and 25 pounds of phosphoric acid.
	2	2	3	Oats: no fertilizer.
2	3	3	4	Wheat: 50 pounds each of phosphoric acid and potash.
3	4	4	5	Clover and timothy: no fertilizer.
		5	6	Timothy: 25 pounds each of nitrogen, phosphoric acid and potash.
			7	Timothy: 25 pounds each of nitrogen, phosphoric acid and potash.*

It is by no means certain that the methods here proposed are the best methods. However, the Pennsylvania Experiment Station, after thirty years of systematic study of this question feels safe in predicting that satisfactory and profitable yields at present prices may be obtained by using any one of these four rotations, if the land is fertilized as suggested, and provided the yields are not limited by other factors, such as lack of drainage, lime, or tillage.

The Pennsylvania Station has maintained the four years' rotation for thirty years. The methods of fertilization have been so nearly identical on certain of its fertilizer plats with the one here suggested as to leave no reasonable doubt that this rotation will maintain the fertility of the soil through any number of generations, provided the other essential factors of plant growth are not lacking. If, after using the fertilizer suggested, difficulties are experienced in getting a good stand of clover, probably drainage or lime or both are needed.

If it is desirable to mow the hay field more than one year. it should be top dressed with manure or with commercial fertilizers as long as the land remains in grass. No hay field should be allowed to remain in grass more than one year unless manure or commercial fertilizers are used. This is a cardinal principle, if the fertility of the soil is to be maintained. Further, there is no more profitable way of building up and maintaining the fertility of the soil than by applying manure or commercial fertilizers to grass lands, nor is there any one of these crops to which commercial fertilizers can be so profitably applied as to the hay.

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* Roughly speaking, 25 pounds each of nitrogen, phosphoric acid and potash may be obtained by buying 150 pounds of nitrate of soda, 175 pounds of acid phosphate and 100 pounds of muriate of potash. The cost of the ingredients may be estimated from the following prices per pound, which will vary according to circumstances: nitrogen, eighteen cents; phosphoric acid and potash each four cents.

In the East there is no land, except that which is overflowed, that should be planted to corn without being fertilized. The average eastern farmer will use a combination of manure and commercial fertilizers during the rotation. In such case, he should apply the manure to his corn ground. If he has manure enough to cover two-sevenths of his cultivated area annually, then he may wisely raise corn two years in succession in the seven-year rotation. If he does not have manure enough for both fields, he should raise corn one year only in the rotation or else he should apply a reasonable quantity of fertilizers, perhaps eight to ten pounds of nitrogen, fifty pounds of phosphoric acid and fifty pounds of potash.

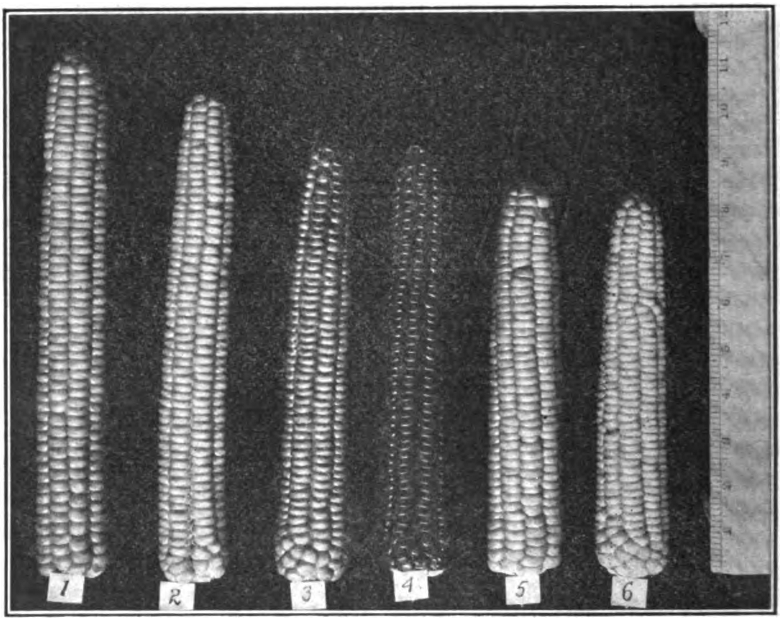

Photo by Department of Agronomy.

Figure II.—Types of flint corn found worthy of special mention: (1) Pennsylvania, Eight-rowed yellow; (2) Massachusetts, Stickney's yellow; (3) Massachusetts, Eight-rowed yellow; (4) New York, Canada Smut Nose; (5) New York, King Philip; (6) Connecticut, Eight-rowed yellow. The Eight-rowed yellow is the common type of flint corn in the states named.

On account of the relatively high percentage of nitrogen and potash in manure, it is wise to add phosphoric acid to it in order that it may be a more nearly balanced fertilizer. It is a good practice to use acid phosphate in the gutters of the stable, as this will absorb the odors and may fix any ammonia that is present. It has not been shown, however, that mixing the fertilizer with manure affords any other advantage over applying it separately.

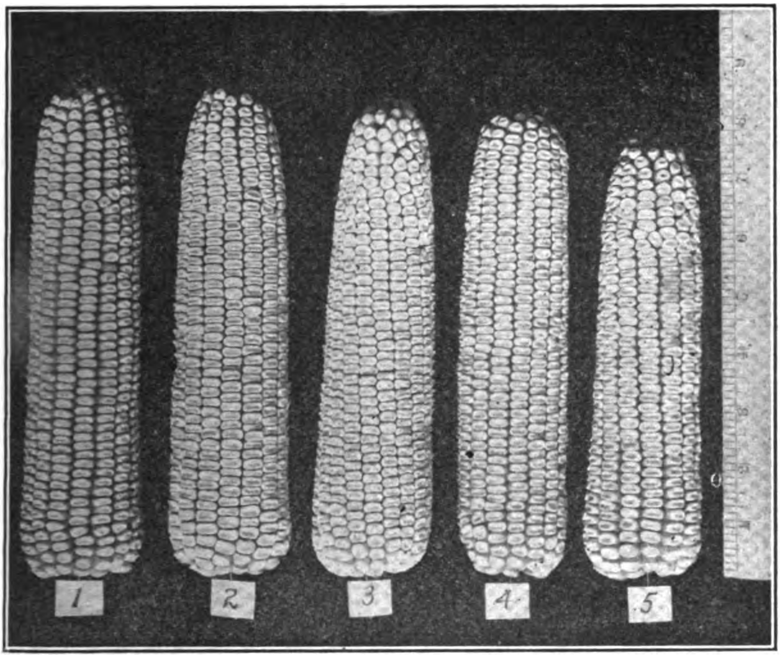

Photo by Department of Agronomy.

Figure III.—Types of early dent corn found worthy of special mention: (1) Connecticut, Pride of the North; (2) New York, Pride of the North; (3) New York, Funk's Ninety Day; (4) Massachusetts, Pride of the North (Sibley's); (5) Pennsylvania, Early Huron Dent. Note the uniformity of the type approved by the Stations of the four states named.

An ear of dent corn has from 800 to 1,000 kernels. There are raised in the United States annually approximately three billion bushels of corn. If, by selection or breeding, or both, a strain of corn were developed which would produce just one more kernel to the ear than the average of the present varieties grown, and if this strain or variety were grown throughout the United States, it is possible that the yield of corn would be increased by three million bushels, worth at present prices one and one-half million dollars. This added income would be produced without cost and without extra effort, except that of handling the extra weight at harvest time. Simple as the process seems, no individual will ever produce a strain of corn that will increase the yield throughout the United States one-tenth of one per cent., because corn is so varied in its adaptability to location. Even in a region so small as the North Atlantic States it has wide varietal adaptations, and in a single state like Pennsylvania the different varieties of corn are so varied in their adaptability that it has never been found possible to prepare a satisfactory classification of prizes for a state corn show.

Some years ago the Pennsylvania Station made a comparative test of eleven varieties of flint corn and fifteen varieties of dent corn during a period of three years, at an elevation of 1200 feet in the central part of the state. The yield of both corn and stover was decidedly in favor of the dent variety, as is shown in the following table:

	Flint	Dent
Grain	1750	3012
Stover	1691	3258
Total	3441	6270

On the other hand, the Cornell Station, three years ago, selected over fifty varieties of flint and dent corn and grew them in an ear-to-row test. Most of these were grown in six different places in New York state. The next year the number of varieties was reduced to that which made only a fair showing. This year the same varieties and a few others were tested again.

Warren writes: "In general the flint varieties have outyielded the dents, both in grain and fodder. Several of our flint corns are apparently better than the dents for silage. One of the best kinds for silage is Hall's Gold Nugget. This does not fully mature for grain. Two of the best kinds of corn for grain appear to be one of the common eight-rowed yellow flints, such as nearly all farmers grow, and King Philip. There are a number of other flint corns, such as Canada Smut Nose, that are practically as good."

A variety may become adapted to a region, although when first grown in the region it is not successful. For five consecutive years, Hartley of the United States Department of Agriculture secured seed from fourteen localities in the Northern States and each year tested all the lots at fourteen different points in the Northern States. In general, the average results for the five years showed the most productive varieties of a section to be those that had for a series of years been grown in that section. Similar results were obtained with varieties of the Central States tested in coöperation with State Experiment Stations of the Central States.

Minns writes, of the Cornell experiments previously mentioned, as follows:

> **"The results show that a few selected varieties of flint corn seem to be superior to many of the others that were tried, but in most localities a locally grown acclimated strain of some flint corn proved to be better than those introduced from other sections in the first year."**

It is advisable to select for general planting some variety with a local reputation. After this has been done, if it is desirable to introduce a variety from another region, secure seed enough for a limited planting, of perhaps one acre, and continue to grow this variety for a number of years before deciding whether or not it is of value. For the practical man, it is probably not worth while to make a close comparative test between the introduced variety and the local variety until the third year. If general observations during the first two years lead to the belief that the variety is a superior one, then make a careful plat test, thus:

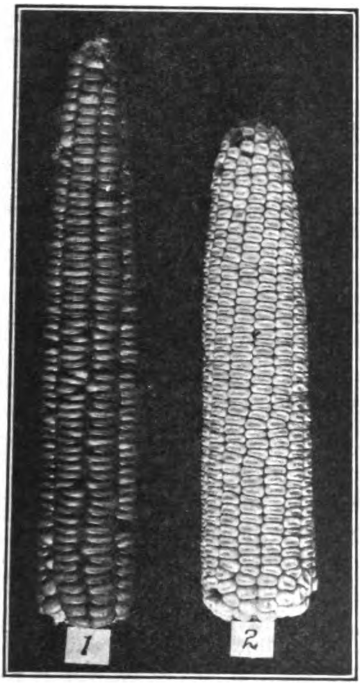

Photo by Department of Agronomy.

Figure IV.—Varieties mentioned for silage by states named: (1) New York, Hall's Golden Nugget; (2) Massachusetts, Rusler White Dent.

Plat 1—Local variety.
Plat 2—Introduced variety.
Plat 3—Local variety.
Plat 4—Introduced variety.
Plat 5—Local variety.

Each plat may contain nine rows, and be any convenient length. If one is not willing to make the extra effort required by using five plats, the test may almost as well not be made. It would serve just as well to use one's own judgment, formed from the general appearance in the field, since with less than five plats the results will be inconclusive.

Several of the Experiment Stations in the North Atlantic States were asked to send a sample ear of one or two varieties of corn which were believed to deserve special mention, either because of the results of the experiments at the station or because of the general experience of the farmers of the state.

Gilbert sent two varieties of dent corn which the Cornell Station has been improving by the ear-to-row method. He writes:

"We are conducting certain corn-breeding experiments in various parts of the state, which are giving us very satisfactory results. The varieties of dent corn which we are using are Pride of the North, Funk's Ninety Day, Leaming, and a local white variety called Winchester County White. We have bred these for about four of five years, and have succeeded in getting strains which give us very satisfactory results, much better than formerly."

Woods, of the Maine Experiment Station, writes, concerning a variety of dent corn with which the Station has been experimenting for some time, as follows:

"It is very early in maturing. During a period of something like twenty years, in which it has been grown in this state, it has never failed to mature thoroughly a crop of seed. It is practically as early as the earliest varieties of sweet corn known. In our experience, the corn has generally passed all danger of frost by the 20th of August, and in the most backward season it will be past danger from frosts by the 1st of September. It is a corn which yields well. While we have no exact figures of large area plats, our observations of it, when grown in different parts of the state and in our own experimental field, indicate that it can be depended upon to yield an average of eighty or more bushels of shelled corn to the acre. This is a very conservative estimate. Under good conditions, it will yield quite a little higher than this of shelled corn. It is a fair to good silage corn. The stalks run from six to eight feet in height, with fairly broad leaves. It is not so heavy in stover, however, as some of the corns which are especially grown for silage purposes.

"The sample of flint corn which we will send you is grown by Mr. Dexter Brunell, of Cumberland Center, in the southern part of the state. This corn, in my judgment, will not yield so well as the dent corn referred to above, but it will come very near doing so. It is early and never fails to mature seed.

Clinton, of the Connecticut Station, sent a sample of dent and one of flint about which he writes:

"These two ears are representative of the corn grown in New England. The dent corn is the Pride of the North, and will yield eighty bushels of shelled corn to the acre. The flint corn is commonly known as the eight-rowed flint, and in yield will not vary materially from that of the dent."

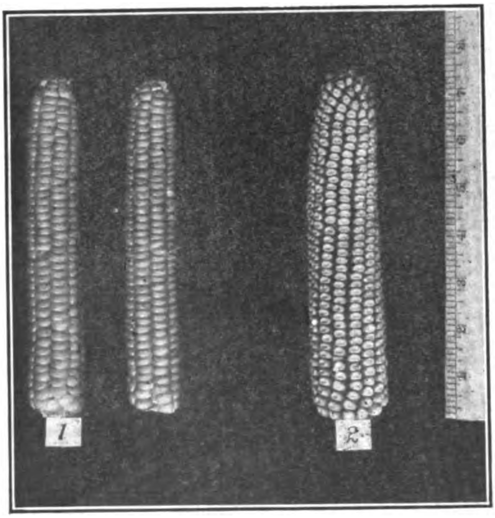

Photo by Department of Agronomy.

Figure V.—Varieties recommended by the Main Station.

Brooks, of the Massachusetts Station, writes:

"I think I shall serve you best if I say that in my judgment the best variety of flint corn will be one of the medium eight-rowed yellow varieties.

No variety would be best for all parts of the state, but these two strains or selections from this class which are especially prominent on account of the success of their growers in winning important prizes. I will ask each of these gentlemen to send you a good specimen ear.

"Dent corn is grown in our state as a rule only in a comparatively small number of towns in the Connecticut Valley. There are two types which may be fairly regarded as at least among the best. One of these is, I think a selection from Sibley's Pride of the North; the other is a variety known as Rusler's White Dent, which I obtained a number of years ago from northern Minnesota."

The Pennsylvania Station has selected five varieties of corn as worthy of special mention. The eight-rowed Yellow Flint and the Early Huron Dent are adapted to the northern portions of Pennsylvania, and to higher elevations elsewhere. The White Cap Dent is the standard variety in central Pennsylvania. The Improved Leaming is suited especially to southwestern Pennsylvania, while the large Yellow Dent is the type of corn raised throughout southeastern Pennsylvania.* It does not follow that there are not better varieties of corn for the East. A man, however, who is starting to grow corn can feel reasonably sure that he is starting with a standard variety if he selects from this list.

When the different samples of corn, submitted by the several stations, are compared, it will be seen that there are two types of corn recommended in nearly every instance, viz., an eight-rowed yellow flint and a medium sized yellow dent to which the name of Pride of the North is usually given. This applies to the whole region of the North Atlantic States, except the more northerly portions of the New England States and the southern portions of New Jersey and Pennsylvania. The proper procedure for the corn-grower, therefore, is to acquaint himself with the type best adapted to his environment, and then to seek it in his own locality. The name under which it happens to be grown is of no consequence. Obviously, for much of the region included in the North Atlantic States, the type will be the eight-rowed flint or a dent of the Pride of the North type. Having selected this type, he should then endeavor to improve it either by field selection or by the ear-to-row method. In general it may be stated that the flint varieties are best adapted to the volusia soils, while the residual soils of Pennsylvania should be planted to dent corn.

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* See front cover. Typical varieties of dent corn grown in Pennsylvania: (1) Southeastern Pennysivania, White Cap Dent; (2) Southeastern Pennsylvania, Yellow Dent; (3) Southwestern Pennsylvania, Improved Leaming; (4) Central and Northern Pennsylvania, White Cap Dent; (5) Northern Pennsylvania, Early Huron Dent.

While the selection of a proper variety of corn is essential to a maximum yield, yet other conditions are often, and perhaps usually, the limiting factors in corn production. One reason for so many inconsistent results in the testing of varieties is that other factors so frequently control the yield.

Some of the factors influencing yield are here briefly summarized.

Period of Growth. The period of growth of a variety of corn must correspond to the growing season of the locality in which that variety was produced. Thus, a variety adapted to Virginia will not ripen in New York; while a variety grown in Maine will mature too early in New Jersey to produce a maximum yield. In transferring a variety to the North or South at a corresponding altitude, the ripening period may be computed to increase or decrease at the rate of one day for each ten miles.

Adaptation to Climatic Conditions. The adaptation of corn to climatic conditions, other than the period of ripening, is not without its influence. A variety of corn taken from Indiana or Illinois to Nebraska, or from these states to Pennsylvania, and planted at the same latitude and altitude, has often proved disappointing for the first two or three years.

Germination. The desirability of perfect germination of seed would seem to be too obvious to mention, and yet its lack is probably one of the principal causes for the reduction of the yield of corn, especially in the eastern part of the United States. No ear of corn should ever be used for seed until six kernels have been tested and found to germinate; not only should these kernels germinate, but they should germinate strongly.* Hartley divided a quantity of seed corn into two lots in the fall, equal in every respect. One of these lots of corn was stored in an ordinary crib, exposed to the usual winter temperature; the other lot was stored in a dry, heated room during the winter. Seed from both lots was used for planting in two places; equal stands were obtained from the seed treated in the two ways. In one field, of rather poor soil, an increase of seven bushels per acre was obtained from seed well cared for; while on better soil the yield was eighteen bushels per acre in favor of the seed stored in a dry, warm room.

Stand. A perfect stand of vigorous seedlings is a prime factor in securing a maximum yield of corn. It is probable that the yield of corn could be increased 20% in the United States, at no added expense, if some method could be devised for securing a vigorous and perfectly uniform stand of seedlings. The number of plants to the acre varies greatly in different parts of the United States and under different soil conditions. The more favorable the soil and climatic conditions, the thicker the planting should be. In central Pennsylvania, it is probable that the maximum yield of grain would be obtained from 10,000 to 12,000 plants to the acre.

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* For the method of conducting germination tests see circular No. 30 of the Department of Agricultural Extension.

When all other conditions are equal, the method of distribution, whether it be that of planting in hills or in drills will not affect the yield. That is to say, the yield will not be influenced by planting one kernel to each foot, two kernels every two feet, three kernels every three feet, or four kernels every four feet. There are, however, three reasons why in practice drilling may give better results than planting in hills. Generally corn is planted too thinly for maximum yields. In drilling, it is customary to use more seed. In practice, the stand is likely to average more uniformly. There is less likelihood of a space of seven to ten feet in the row where there are no plants. The third reason why drilling may give better results is that the corn cannot be cultivated both ways. Hence, where deep cultivation is practiced, root pruning is less severe.

Two factors entering into the problem of securing a uniform stand of corn plants are (1) the germinating power of the seed, and (2) the uniformity of the size and shape of the seed. Corn should not be used for planting unless the kernels are uniform in size and shape. One reason for growing corn true to type is to secure seed kernels of uniform size and shape. This is the reason why the kernels at the butts and tips are rejected.

Preparation of the Seed Bed. A thorough preparation of the seed bed is of prime importance for corn. Advice to cultivate corn before it is planted cannot be too strongly emphasized. The seed bed should be deeply and loosely pulverized. The seed bed for corn differs in this particular from the seed bed for wheat, which should be compacted. A disc harrow is—when the presence of stones does not prohibit its use—the ideal tool for preparing the seed bed for corn, while a spring-tooth harrow will bring about suitable conditions for wheat.

Cultivation. The purposes of intercultural tillage are (1) to kill weeds, (2) to keep the surface soil receptive to rainfall, (3) to prevent the evaporation of soil moisture. Cultivating corn four inches deep as compared with two inches deep may reduce the yield 10% owing to pruning the roots. Four or five cultivations are usually sufficient. More frequent cultivations have not been shown to increase the yield when the soil is not unduly compacted from heavy rainfall, provided it is free from weeds.

One acre out of every three that is plowed each year in the United States is planted to Indian corn. It is the crop that characterizes and sets apart the agriculture of this country from that of every other nation upon the globe. Its greater value per acre lies at the foundation of America's material prosperity.

Sun Ptg. & Bdg. Co., Williamsport, Pa.

William [illegible]

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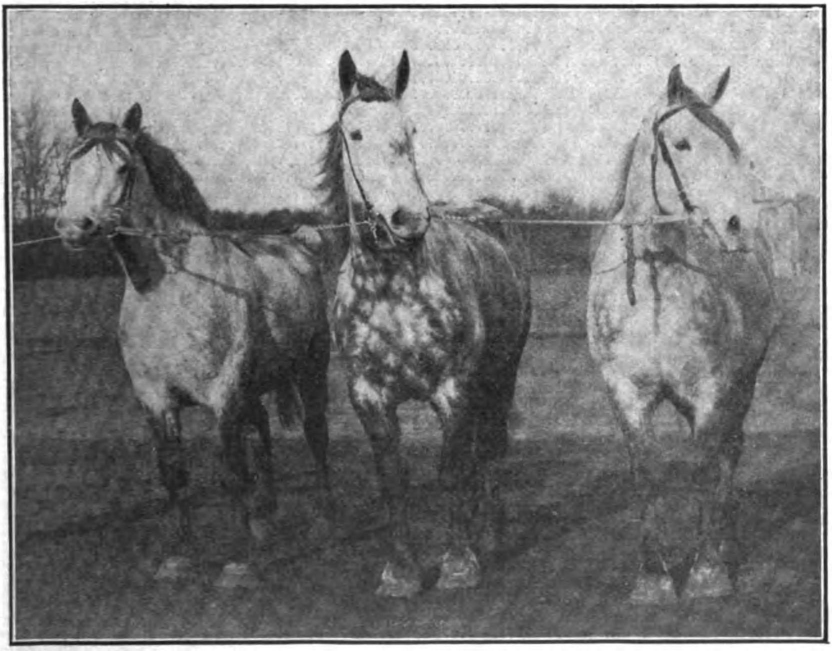
The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 117



FEEDING DRAFT HORSES

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AUGUST, 1912

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* Absent on leave.

Sun Ptg. & Bdg. Co., Williamsport, Pa.

The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 117

FEEDING DRAFT HORSES

BY W. A. COCHEL

SUMMARY

1. Silage, which is made from mature corn, is free from mould, has not been exposed to air too long before feeding and is properly supplemented with other feeds which will make up the deficiency in protein, can be fed to horses with safety when care is used to have them become gradually accustomed to it.

2. Horses fed silage as a portion of their ration consumed less grain, made their gains at lesser cost per pound, were sleeker and better finished than when fed on rations not containing silage.

3. Using cottonseed meal to replace oats resulted in a cheaper ration, a larger gain, smaller cost of gain and a higher finish in fattening horses.

4. The cost of gains varied from 13.4c to 17.7c per pound; the rate of gain, from 1.59 pounds to 1.78 pounds per head daily, due to selections of rations for fattening purposes.

5. The cost of gain due to individuality of horses in Group 1 varied from 9.54c to 19.83c; in Group 2, from 10.83c to 19.05c; and in Group 3, from 11.53c to 29.63c per pound.

6. The rate of gain depends upon the ration used and the temperament, disposition, age, condition and type of individual.

7. The most profitable horse for feeding purposes is one that shows every evidence of draft blood, with clean, short legs, wide cannons, deep and wide both in chest and in middle, showing constitution and capacity throughout.

8. There is little change in depth of body or length of body from fattening, the greatest change being an increase in width and an apparent improvement in the spring of rib.

9. The greatest changes in form due to fattening are noted in those parts of the body where the natural covering of muscle is thickest.

10. The height at withers is greater in a thin horse than the height at croup. When finished, the height at croup is greater than that at withers.

Fig. 1. Twenty-one horses used in experiment.

A Study of Oats vs. Cottonseed Meal and Mixed Hay vs. Corn Silage

Horses are not only fed on a larger number of farms, but are more widely distributed in cities and towns, than any other kind of livestock. Their feeding is, therefore, of almost universal interest. There are usually one or more of three dfferent objects in view in horse feeding—to maintain health and condition, to enable them to expend a greater amount of energy at work, or to improve in general appearance either as a matter of personal pride of the owner or to enhance their market value. The condition or the amount of fat deposited on a horse increases his market value more than that of animals fattened for the block. It is also true that rations which cause an economical increase in weight may be generally considered as economical in furnishing energy for work. For this reason it was considered advisable to conduct an experiment with a view to obtaining accurate information as to the relative value of different feeds for fattening purposes.

In feeding horses for market, the cost of gains is not the only factor which determines the profit or loss from the operation. Market values fluctuate quite widely during the time necessary for feeding, hence there may be a considerable profit or loss due entirely to this factor. Horses that are kept in idleness are quite apt to become blemished or injured on account of playfulness in the stable. The risk of sickness is greater than with cattle, sheep and hogs. Many horses are unable to stand a long period of forced feeding because of constitutional weakness. Good judgment in buying and selling is necessary. All other conditions being equal, a close study of the selection of rations and methods of feeding will determine the success or failure of those who finish horses for market.

Object of the Experiment

The object of this experiment was to obtain data in regard to the efficiency of three different rations for fattening purposes. As practically all of the horses in the stall are fed home grown feeds, a ration composed of corn, oats and mixed hay, which is generally used, was selected as a basal ration. As the digestible nutrients in oats are usually much more expensive than in concentrated nitrogenous feeds, cottonseed meal was used in place of oats in one of the groups to determine whether the less expensive ration of corn, cottonseed meal and hay was equally as efficient as one of corn, oats and hay. As corn silage furnishes digestible nutrients at a lesser cost than any other roughage grown in the state, a ration of corn, cottonseed meal, hay and silage was used in comparison with one of corn, cottonseed meal and hay to determine whether horses could be fed silage without detriment to health or reducing the efficiency of the ration. Observations were made of the health of the horses, rate of gain, economy of gains as measured by the amount and cost of feeds consumed, changes in conformation due to increase in weight, influence of type, condition and temperament of individuals upon their behavior during the finishing process.

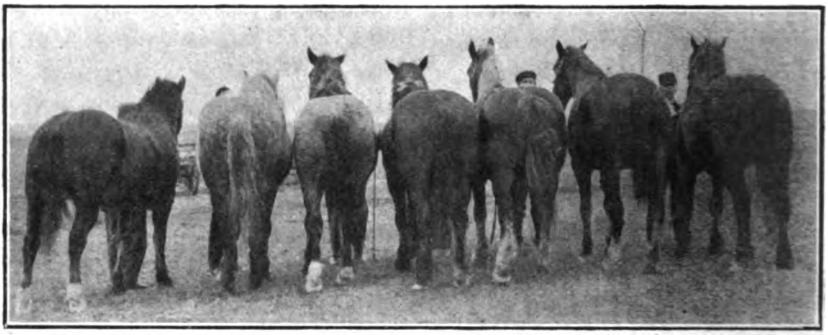

Fig. 2, Group I. Ration: Shelled corn, cottonseed meal, mixed hay and corn silage.

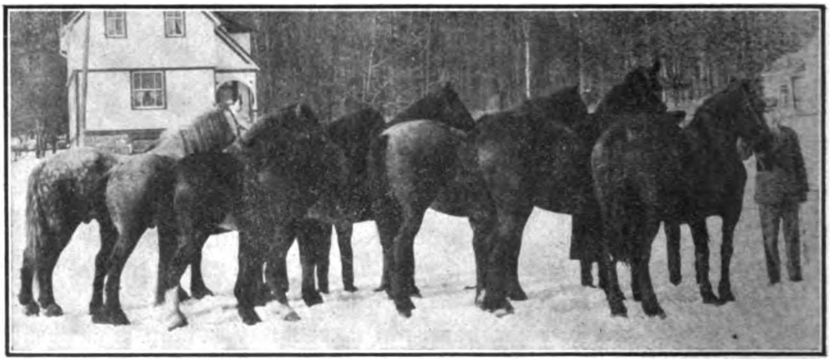

Fig. 3, Group II. Ration: Shelled corn, cottonseed meal and mixed hay.

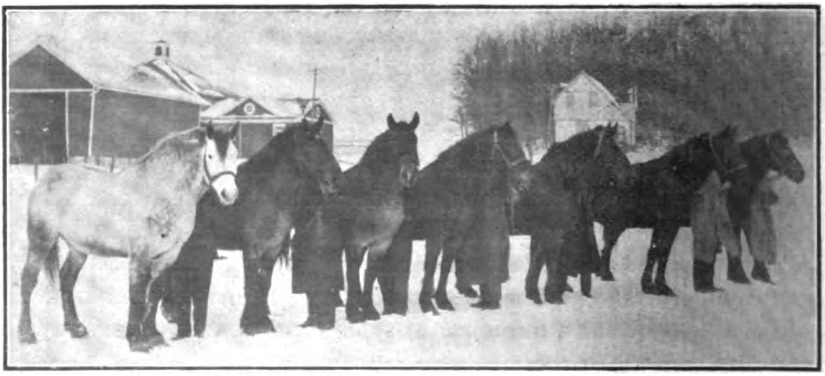

Fig. 4, Group III. Ration: Shelled corn, oats and mixed hay.

Horses Used

Twenty-one horses were used in this experiment. Seventeen of these were purchased on the Chicago market in August. The remaining four used were taken from teams formerly used on the College farms. There were eighteen geldings and three mares in the entire lot. The predominating blood was Percheron and Belgian. The ages varied from four to eight years. The type represented was what is known on the market as "chunks" or light draft.

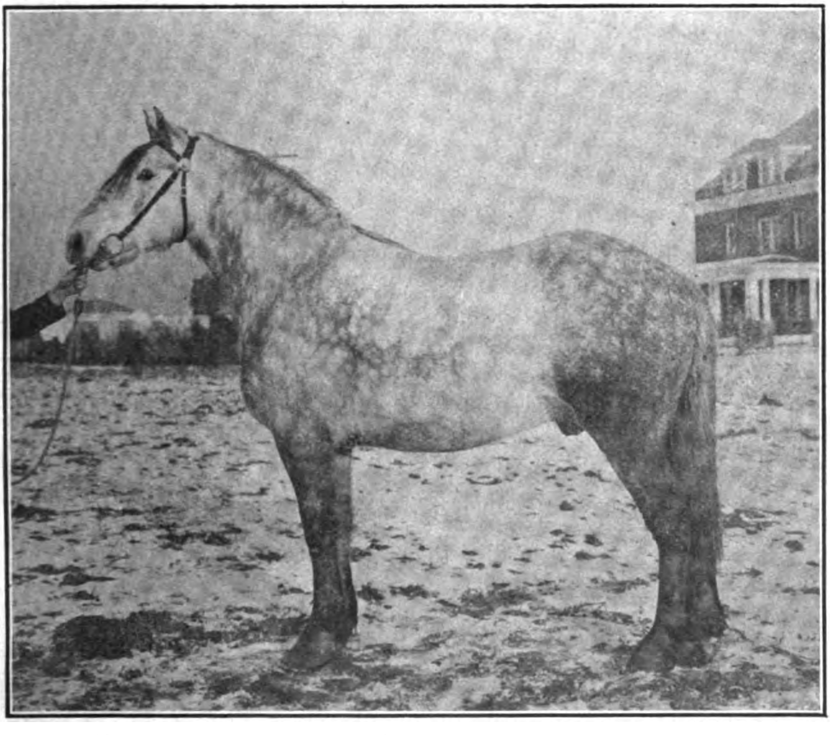

Fig. 5. Horse No. 1. Group I. Gain 195 pounds at a cost of 9.54 cents per pound. Temperament and type which insures rapid gains.

Plan of the Experiment

The horses were divided into three groups of seven each, as nearly equal in age, size, sex, condition, conformation, temperament and weight as possible. The horses in group one were numbered from 1 to 7, inclusive; group two, from 10 to 16 inclusive;

and group three from 20 to 26, inclusive. They were fed for a period of 84 days. For convenience, this time was divided into three periods of 28 days each. The initial weights of the horses were secured by weighing them three consecutive days under simlar conditions and taking an average of the three weights. In each instance, the horses were weighed after feeding but before watering in the morning. At the middle of each period of 28 days, they were weighed one day and at the close of three consecutive days, the first weight being taken the day prior and the last weight on the day subsequent to the days marking the close of that period.

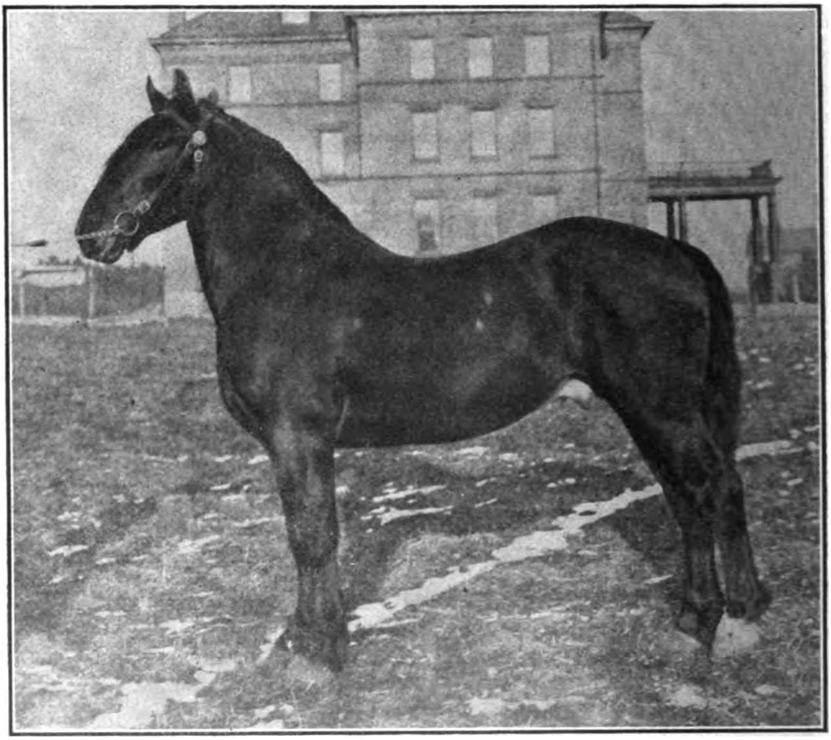

Fig. 6. Horse No. 5. Gain 91.7 pounds at a cost of 19.83 cents per pound. Temperament and type unsuited for rapid gains.

During the experiment the horses were housed in the basement of the general stock and storage barn on the College farm. They were tied in single stalls five by eight feet, without exercise, except when they were led approximately 100 feet to water at 8:00

A. M. and 4:30 P. M., and when weights were taken at a scale 100 feet from the barn door, throughout the entire experiment. The light and ventilation in the barn were only fair or as would be found in the average Pennsylvania barn. The floor of the stable was of earth. The temperature was warm enough so that water did not freeze at any time during the experiment.

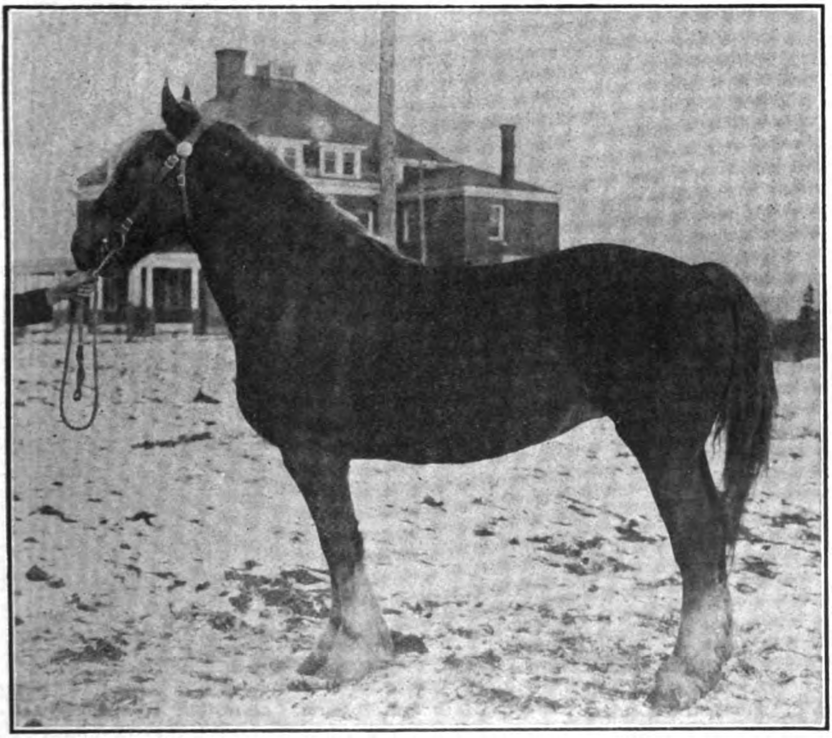

Fig. 7. Horse No. 6. A short back; deep, wide body; large, clean flat bone; short legs, which are characteristic of ideal draft horses.

Method of Feeding and Rations Fed

Grain was fed three times daily—at 6:30 A. M., 12:00 M. and 5:00 P. M., the grain for each horse being weighed separately. All horses were started on the same amount of feed, which was gradually increased until each individual was consuming as much as he would clean up nicely. Groups two and three received hay both morning and evening; group one, silage in the morning and hay in the evening. The hay was weighed out separately for each group and divided as nearly equally as possible among the seven horses. Silage was weighed and fed to each individual horse in the morning in order to observe any evidence of digestive disorder due to its use.

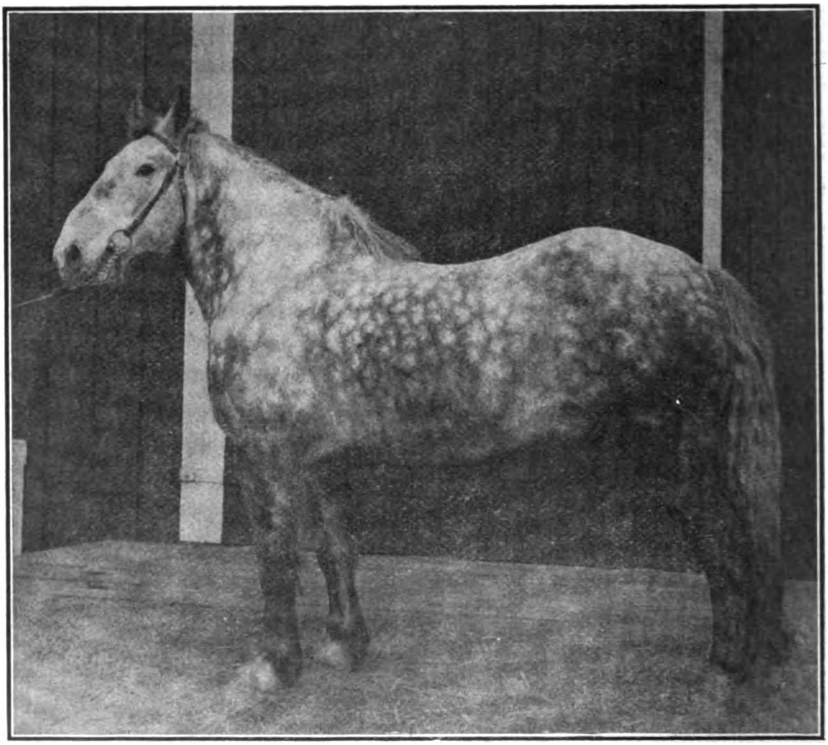

Fig. 8. Horse No. 16. Group II. Gain 201.7 pounds, at a cost of 10.83 cents per pound. This horse made the most rapid gains of any in the experiment.

The rations fed were as follows:

Group I—Corn, cottonseed meal, corn silage, mixed hay.

Group II—Corn, cottonseed meal, mixed hay.

Group III—Corn, oats, mixed hay.

Each horse was started on a grain ration of eight pounds per head daily, which was increased at the rate of one pound daily for the first week, after which it was one-half pound until the horses would no longer consume additional grain. Hay was fed at all times according to the appetite of the individual horses, care being exercised to prevent waste. Silage was fed in Group 1 at the rate of five pounds per head daily at the beginning, which was increased gradually to twenty pounds which was all that the horses seemed to relish. It was fed in the morning, so that any digestive disorders due to its use could be easily noticed.

Quality and Cost of Feeds

The corn and oats were grown on the College farms and of excellent quality. The cottonseed meal conformed to the standard of "choice cottonseed meal." The hay was a mixture of clover and timothy, approximately half and half and of splendid quality, free from dust. The corn silage was not of a very high quality, due to immaturity when harvested. The silo was not perfectly airtight and consequently some of the silage was mouldy. However, as far as possible, this was eliminated at the time of feeding.

Prevailing local prices during the progress of this experiment were: corn, 50c per bushel; oats, 35c per bushel; cottonseed meal, $32.00 per ton; mixed hay, $12.00 per ton, and corn silage, $2.50 per ton.

Health and Thrift of Horses

All horses entered in the experiment remained throughout the test, there being no changes or substitutions during the entire 84 days. A few of the horses did not relish cottonseed meal, and in such cases linseed meal was substituted in its place for a few days. Horse No. 2 had a slight attack of periodic opthalmia during the third period. Horse No. 7 refused to eat the allowance of corn silage of 20 pounds daily. Horse No. 3 became quite sore and stiff during the last period, due to an attack of laminitis, from which he fully recovered after the close of the test. Horse No. 22 injured his hock from kicking against the side of his stall. Horse No. 23 refused one feed during the first ten days of the experiment. Horse No. 24 showed a slight unsoundness in wind at the close of the experiment. These include all of the unsoundnesses which developed in the 84 days during which the test was in progress.

SUMMARY OF HORSE FEEDING EXPERIMENT—Nov. 3, 1910, to Jan. 26, 1911

Horse No.	Group	Initial Weight	Final Weight	Gain	FEED CONSUMED							Total Cost of Feed	Cost per Pound Gain
					Shelled Corn	Corn Silage	Cotton-seed Meal	Bran	Oats	Oil Meal	Hay		
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.		
1	1	1535.0	1730.0	195.0	1081.1	1531.	118.0			3.5	873.4	$18.618	9.54c
2	1	1456.6	1561.6	105.0	1113.6	1527.	124.9				873.4	18.954	18.05c
3	1	1480.0	1593.8	113.8	884.9	1486.	115.9	50	24		873.4	17.653	15.51c
4	1	1470.0	1603.3	133.3	982.6	1457.	125.4				873.4	17.705	13.28c
5	1	1416.6	1508.3	91.7	1049.6	1536.	101.9			9.5	873.4	18.192	19.83c
6	1	1460.0	1618.3	158.3	1114.1	1399.	115.4			10.5	873.4	18.812	11.88c
7	1	1353.3	1496.6	143.3	988.1	1040.3	98.9			12.0	933.6	17.377	12.12c
Total		10171.5	11111.9	940.2	7214.0	9976.3	800.4	50	24	35.5	6165.2	$127.311	
Average		1453.07	1587.41	134.36	1030.5	1425.2	114.3				880.7	18.187	13.4c
10	2	1380.0	1533.3	153.3	961.6		95.3			25.1	1522.9	$19.519	12.73c
11	2	1570.0	1696.6	126.6	1219.1		128.1				1522.9	21.932	17.32c
12	2	1386.6	1500.0	113.4	1188.1		124.6				1522.9	21.603	19.05c
13	2	1450.0	1588.3	138.3	1042.1		115.4				1522.9	20.153	14.57c
14	2	1396.6	1563.3	166.7	1042.6		128.6				1522.9	20.361	12.21c
15	2	1373.3	1520.0	146.7	1042.6		127.5				1522.9	20.348	13.87c
16	2	1646.6	1848.3	201.7	1233.6		113.8				1522.9	21.847	10.83c
Total		10203.11	11249.8	1046.7	7729.7		833.3			25.1	10660.3	145.763	
Average		1457.58	1607.11	149.53	1104.2		119.04				1522.9	20.823	13.9c
20	3	1600.0	1741.6	141.6	767.5				676		1487.2	$24.219	17.10c
21	3	1448.3	1558.3	110.0	788.5				676		1487.2	24.406	22.18c
22	3	1496.6	1578.3	81.7	766.5				676		1487.2	24.210	29.63c
23	3	1466.6	1548.3	81.7	781.5				666		1487.2	24.210	29.63c
24	3	1413.3	1581.6	168.3	767.5				676		1487.2	24.219	14.39c
25	3	1386.6	1560.0	173.7	767.5				676		1487.2	24.219	13.94c
26	3	1368.3	1578.3	210.0	767.5				676		1487.2	24.219	11.53c
Total		10179.4	11146.4	967.0	5406.5				4722		10410.4	$169.702	
Average		1454.2	1592.3	136.7	772.3				674.5		1487.2	24.243	17.77c

From the data presented in the table, it will be noticed that the feeding of corn silage resulted in a slight decrease in total grain consumption as well as a marked decrease in roughage. When cottonseed meal was substituted for oats, the result was a marked decrease in the consumption of grain and a slight increase in that of hay.

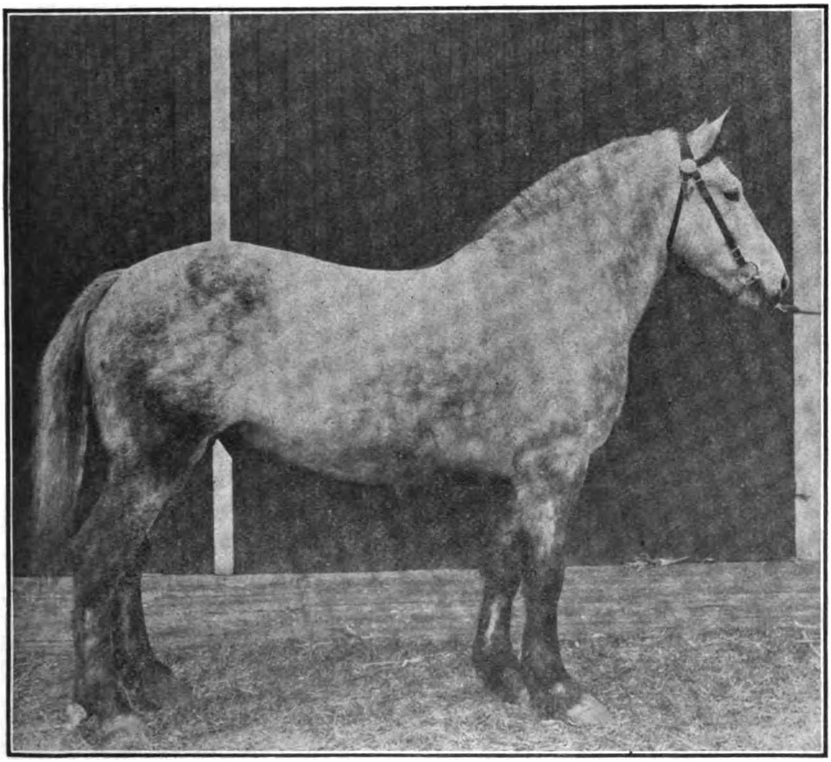

Fig. 9. Horse No. 16. Group III. Gain 141.6 pounds, at a cost of 17.1 cents per pound. The most profitable horse in the experiment.

The average cost of gains varied from 13.4c in the silage fed lot to 17.7c per pound in the lot receiving oats. It is generally agreed among horse buyers that the value of a draft horse increases $25.00 for each additional hundred pounds of weight, which would show a profit, under normal conditions, varying from $6.30 to $12.60 on each hundred pounds increase in weight during the feeding period.

The ability of a horse to lay on flesh is largely a matter of individuality controlled by disposition, temperament, age, condition, digestive capacity and type. The average gains made by horses weighing over 1450 pounds at the beginning of the experiment were practically the same as those of lighter horses, which would seem to indicate that weight is not a controlling factor in making gains. Mature horses, 6 to 7 years of age, made more satisfactory gains than those 4 to 5 years of age. A higher finish was secured on the mature individuals. The most profitable type of horse for feeding purposes is one which shows every evidence of draft breeding, with clean, short legs, wide cannon, depth and width in chest and middle, showing constitution and capacity throughout.

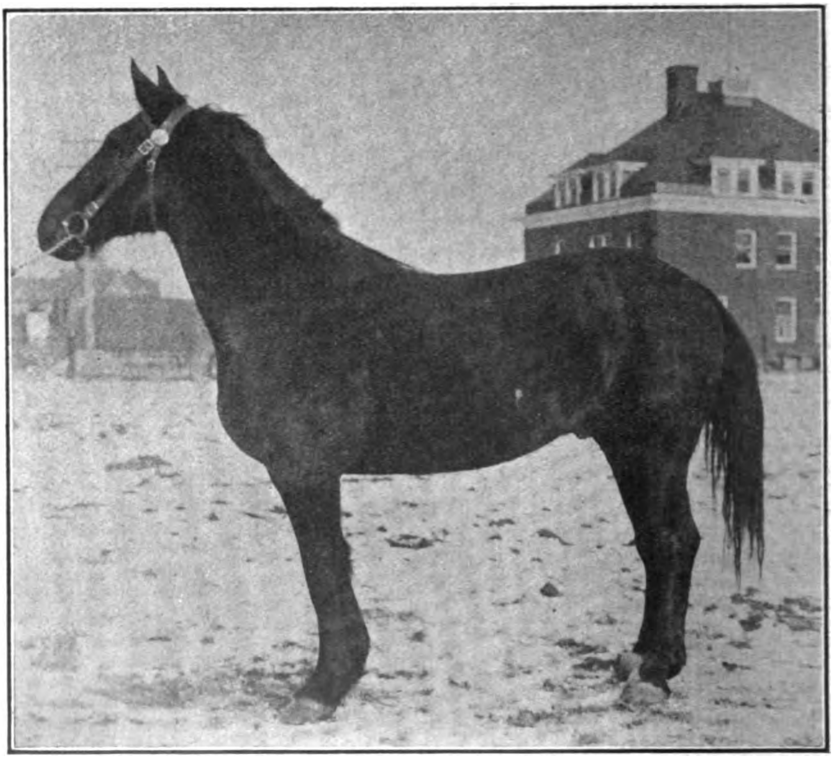

Fig. 10. Horse No. 23. Group III. Gain 81.7 pounds. at a cost of 29.63 cents per pound. This horse made the smallest gains of any in the experiment, due to deficiency in type, constitution and lack of middle.

Changes in Form Due to Fattening

A record of the outline of the chest and of the middle of the paunch of each individual horse was made at the beginning and close of the experiment by means of an adjustable chain, for the purpose of determining where the fat was placed on the body. An average of chest and middle girths of the entire lot of horses is shown by the accompanying charts.

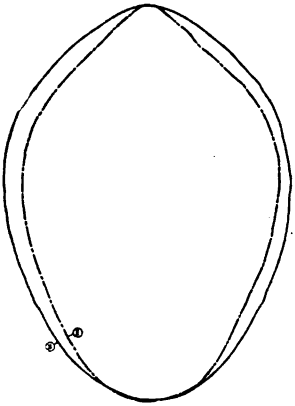

Fig. 11. Chart showing average outline of chest for twenty draft horses at beginning and close of experiment.

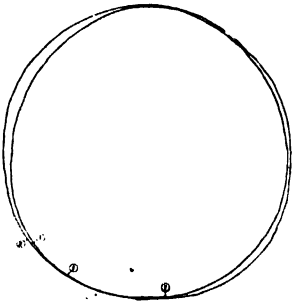

Fig 12. Showing average outline at middle of paunch for twenty draft horses at beginning and close of experiment.

It will be seen from these charts that there was little change in depth of body, especially at the heart girth, that there was an apparent improvement in the spring of rib and a very material increase in the width of body throughout. It would seem from these measurements, as well as those showing lineal measurements, that the greatest change in form due to the fattening process is noted in those parts of the body where there is the heaviest covering of muscle and that in those regions where there is little muscle the changes were insignificant.

One very marked change in the form of the chest is noted in the location of the point of greatest width, which is nearly two inches higher in the fat animal than in one in thin condition. There is a smoothness in outline and rotundity of form after fattening which is entirely absent before the finishing process is started.

In the outlines of the middle of paunch of thin horses, there is a flattened appearance above the median line, while the same measurements after fattening result in almost a perfect circle.

While there is some change in the lower half of the middle girth, the greater change in the upper half eliminates from the fat animal that degree of paunchiness which is displeasing, and adds very much to neatness of the individual.

As a few of the horses used in this experiment were kept on the College farms at heavy work immediately after the close of the experiment, it is interesting to note that as they lost in weight and condition, they assumed a form similar to that which they had before the fattening period.

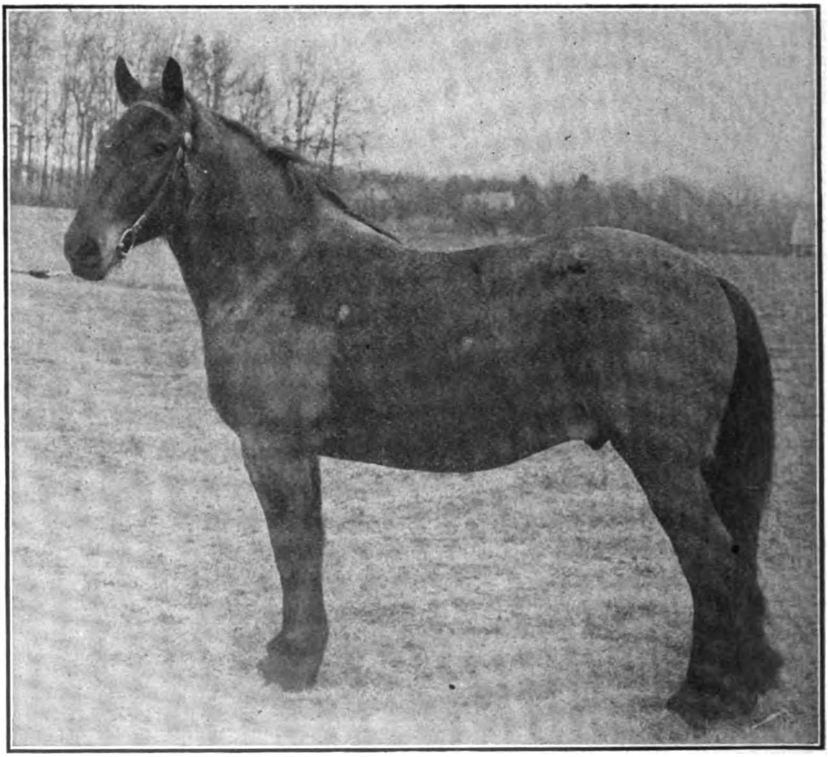

Fig. 13. Horse No. 12. Group II. Gain 113.4 pounds, at a cost of 19.05 cents per pound. An individual with type, quality and temperament suitable for efficient work. Note exceptional back and loin.

These changes are so striking as to need little or no comment, but show that the horse at hard work may not only utilize his daily rations for the production of work but may draw upon the reserve energy which is stored up in the form of fat on his body.

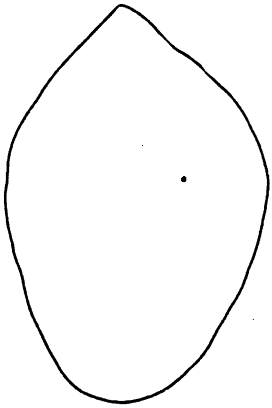

Fig. 14. Horse No. 4 at beginning of experiment

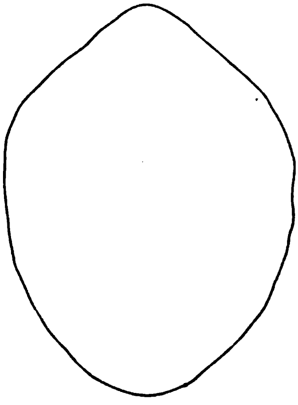

Fig. 15. Horse No. 4 at close of experiment

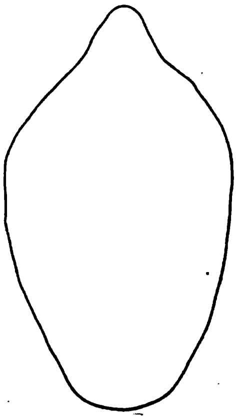

Fig. 16. Horse No. 4 after six months' hard work

Figures 14, 15 and 16 show changes in cross section of chest of horse No. 4 from beginning of experiment to close, and after six months' hard work

Table Showing Average Lineal Measurements of Horses

Date	Nov. 2, 1910	Jan. 27, 1911	Increase	Decrease
Length of head	26.42 in.	26.62 in.	.20 in.	
Height of withers	64.02 in.	64.43 in.	.41 in.	
Length of shoulder	27.03 in.	27.17 in.	.14 in.	
Width of chest	17.31 in.	20.95 in.	3.64 in.	
Chest to ground	32.67 in.	32.77 in.	.10 in.	
Scapula to hip	29.97 in.	29.93 in.		.04 in.
Height at croup	63.79 in.	64.46 in.	.67 in.	
" at hind flank	42.07 in.	41.99 in.		.08 in.
Width of hips	23.65 in.	24.23 in.	.58 in.	
Length of croup	25.07 in.	25.74 in.	.67 in.	
Hock to ground	24.50 in.	24.74 in.	.24 in.	
Girth at heart	79.00 in.	82.66 in.	3.66 in.	
" " middle	89.25 in.	92.55 in.	3.30 in.	
" " hind flank	80.95 in.	83.90 in.	2.95 in.	
Weight	1454.9 lbs.	1595.6 lbs.	140.7 lbs.	

The table of lineal measurements shows that there was very little change in the length of head and shoulder and distance from chest and hock to ground. The length of back as measured from scapula to hip decreased slightly, due to a deposit of fat over hips, and immediately behind the scapula there was an apparent lowering of the hind flank. The losses in these two measurements, however, are so slight as to be within probable error of measurements. There was an increase in height both at withers and croup which may in part be accounted for by growth in hoofs, although it will be seen that the relative height at these two points changed during the progress of the feeding period. At the beginning the horses were higher at withers, but when finished were higher at croup. This is doubtless due to the deposit of fat within the heavy muscles over the hips. While there were material increases in both the width and length of croup, the change in middle of chest is so much more marked as to deserve attention.

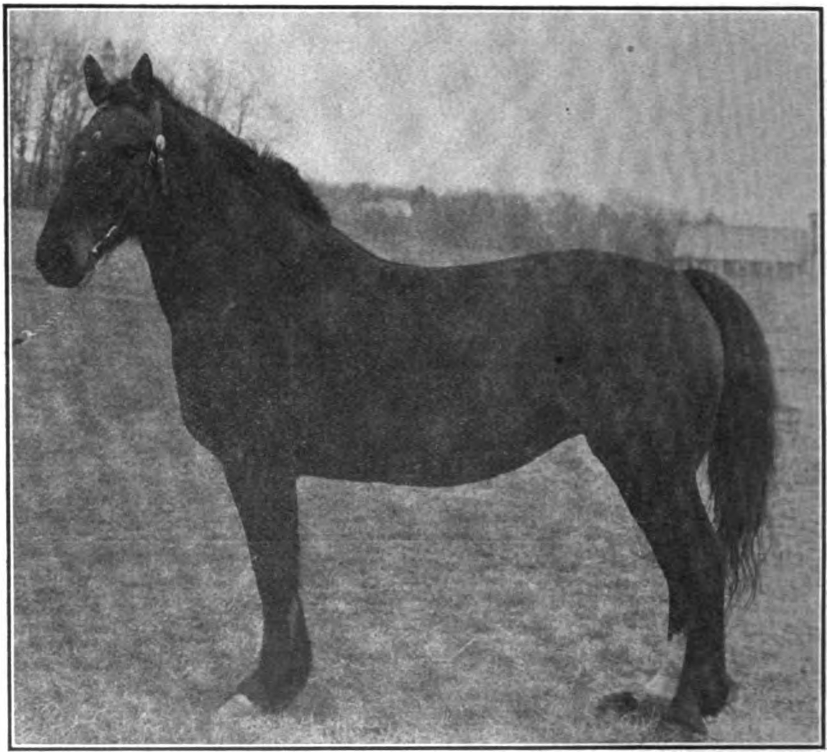

Fig. 17. Horse No. 20. Group III. Gained 210 pounds, at a cost of 11.53 cents per pound. A useful type of mare, suitable for the production of draft geldings.

The heavy muscles both in front of and behind the scapula are so situated that any deposit of fat within them would cause a material change in the width of chest, while the pelvic bones are rigid and the place of measurement is not materally affected by thickness of muscle, thus any change in these regions would be due to a deposit of nearly pure fat over the outside of the body rather than within it. All girth measurements showed marked increase as would be considered probable. While additional data should be secured along these lines before final conclusions are made, the results here presented seem to indicate that the greatest change in fattening horses is one of width rather than depth, that the smoothness, symmetry and general appearance are greatly improved by the "rounding out" process due to deposit of fat within the muscles and that the form of the individual is largely a matter of condition, while the type is almost entirely due to breeding.

LIST OF PUBLICATIONS AVAILABLE

The following publications of the Experiment Station are now available and will be mailed free on application:

Reports 1897, 1898-9, 1900-1, 1901-2, 1902-3, 1903-4.
Bulletin 38. Test of Hand Separators.
Bulletin 49. Field Fertilizer Experiments on Tobacco.
Bulletin 61. Report of the Director.
Bulletin 72. Experiments in Growing Sumatra Tobacco Under Shelter Tent, 1903.
Bulletin 89. Shelter Tent Experiments with Tobacco.
Bulletin 94. Variety Tests of Wheat.
Bulletin 95. Pig Feeding Experiments.
Bulletin 96. Cabbage Strain Test.
Bulletin 97. Milling and Baking Test.
Bulletin 101. Meadows and Pastures.
Bulletin 102. Steer Feeding.
Bulletin 103. Lighting of Farm Houses.
Bulletin 104. The Respiration Calorimeter.
Bulletin 105. Influence of Type and Age Upon Utilization of Feed by Cattle.
Bulletin 106. The Apple in Pennsylvania.
Bulletin 107. Poultry Experiments and Management.
Bulletin 108. Variety Tests of Oats.
Bulletin 109. Soiling Crops for Pennsylvania.
Bulletin 110. Control of Insects and Crop Diseases.
Bulletin 112. Beef Production in Pennsylvania.
Bulletin 113. Experiment Station Abstracts.
Bulletin 114. Dairy Rations.
Bulletin 115. Lime Sulphur Spray.
Bulletin 116. Corn Growing in the East.
Bulletin of Information No. 2—Composition of Full Cream Cheese.

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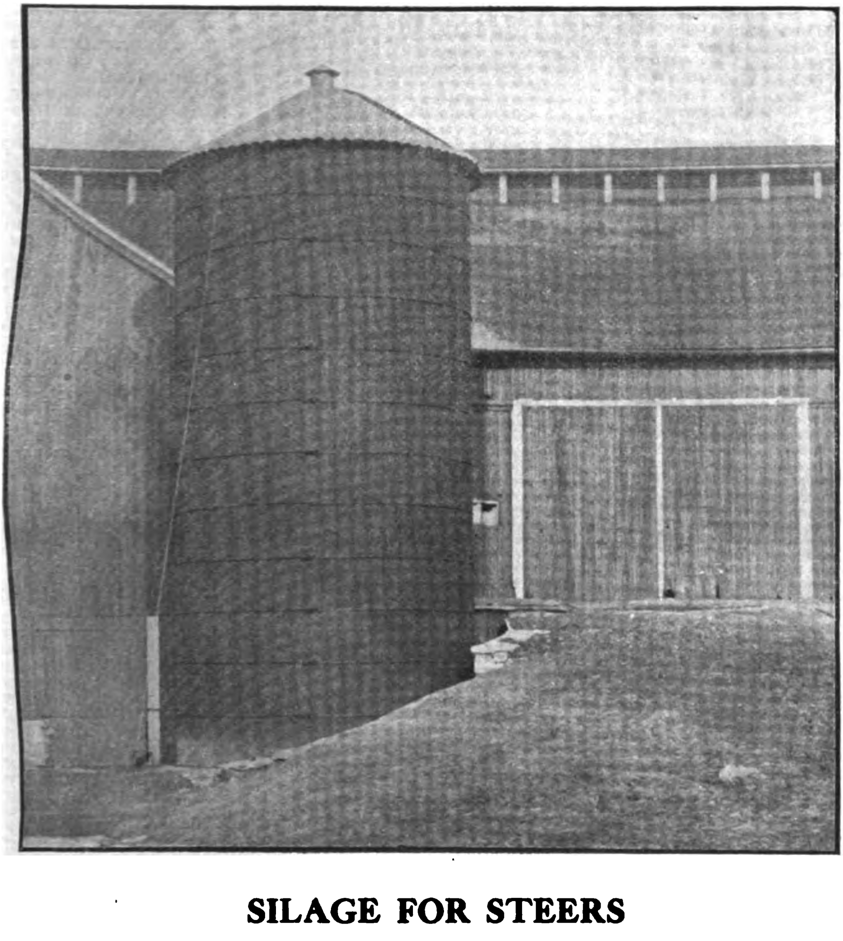
The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 118



SILAGE FOR STEERS

WINTERING BEEF BREEDING COWS

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
OCTOBER, 1912

AGRICULTURAL EXPERIMENT STATION
THE PENNSYLVANIA STATE COLLEGE

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The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 118

SILAGE FOR STEERS

By W. A. COCHEL

As the value of hay, corn, and other feeds generally used for fattening beef cattle, has shown a tendency to increase very rapidly, many who consider it necesary to finish steers for market in order to keep up the fertility of the soil are tempted to abandon the making of beef, to sell the grain and roughage produced, and to depend upon restoring the plant food to the soil in the form of

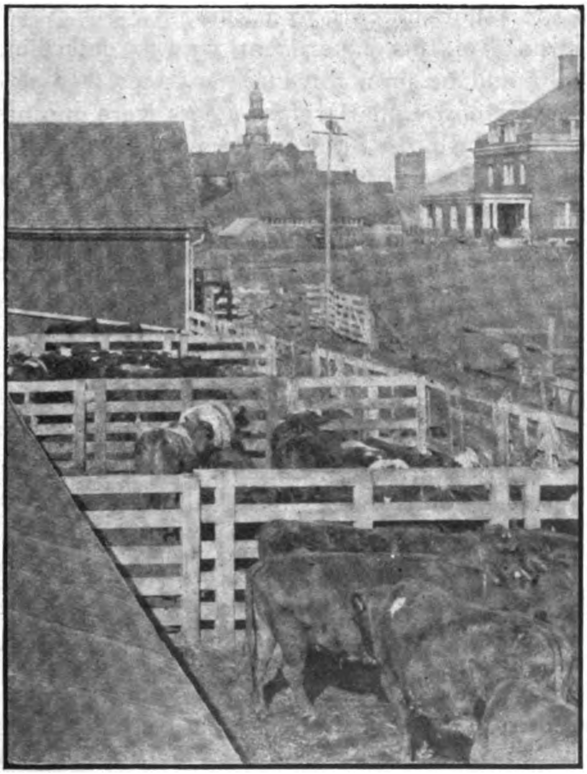

Figure 1. Steers used in silage experiments, winter of 1911-12.

green manures and commercial fertilizers. This experiment is a continuation of the work previously reported in Bulletin 102 and the Annual Report of the Pennsylvania School of Agriculture and Experiment Station for the year ending June 30, 1911, which has been carried on in order to determine profitable methods of steer feeding under Pennsylvania conditions.

Experiments at this and other stations have shown that the addition of corn silage to the rations that are usually fed to fattening animals results in cheaper and more rapid gains in the feed lot, and that its succulent nature causes cattle to shed the hair early and to look more attractive than those fed exclusively on dry feeds. A further advantage in Pennsylvania is that an excellent quality of corn silage can be produced in localities where the season is too short for corn to mature.

The purpose of this experiment was to determine to what extent silage could be profitably used in steer feeding. Twenty-seven grade Shorthorn and Hereford steers were purchased on the open market in Pittsburgh for this purpose. Three of them were used for other purposes, and the remaining twenty-four were entered in the silage test.

The Cost of Cattle at Market vs. Cattle Delivered In Feed Lots.

In order that a full and complete record of the cattle may be available, the following data are inserted.

Nov. 16	To 23 cattle, wt. 19,450 lbs., @ $4.90 per cwt.		$953.05
	To 4 cattle, wt. 3,340 lbs., @ $5.00 per cwt.		167.00
	To Freight, Pittsburgh to State College		34.36
Dec. 1	Feeds used preliminary to beginning of test:		
	Mixed hay, 6310# @ $12.00 per ton	$37.86	
	Corn silage, 6100# @ $2.50 per ton	7.62	
	Cottonseed meal, 90# @ $30.00 per ton ..	1.35	46.83
	Total cost of 27 cattle, Dec. 1, 1911		$1,201.24
	By Value of 3 cattle used for other purposes		127.03
Total cost of 24 cattle at beginning of experiment			$1,074.21
	Total weight of 27 cattle, Dec. 1. 1911		23,692 lbs.
	Total weight of 27 cattle, Nov. 13, 1911		22,790 lbs.
	Gain during preliminary feeding period		902 lbs.
	Average gain per head		33.5 lbs.
	Total weight of 24 experimental steers		21,175 lbs.
	Average cost per cwt.		$5.07

It will be seen from the above data, that the cost of the cattle delivered in the feed lots, after paying freight and preliminary feeding expenses, was 16 cents per hundred more than their cost in the yards. The hay used during this period was of inferior quality and the silage was damaged to some extent, hence the price is lower than for that used in the experiment. During this period, 12 of the steers were dehorned in order that they might not be a source of disturbance to others which had been dehorned before purchase.

The cattle classified as fair to good feeding cattle. They showed evidence of an infusion of beef blood upon a "scrub" foundation. They did not possess the weight, type, quality or condition of the best feeding cattle, but were selected with a view to having a lot of steers that would represent an average grade used throughout the state. They cost approximately one dollar per hundred less than quotations of choice to fancy cattle upon the Chicago market at the time of purchase.

Method of Feeding and Sheltering.

The 24 steers were divided into two lots as nearly alike as possible in age, weight, breeding, quality, condition and temperament, designated as Lot I and Lot II. The steers in each lot were given all of the corn silage they would consume and two pounds of cottonseed meal per head, daily. As previous experiments at this Station* have shown that a limited grain ration was more profitable than a full feed during the early part of the fattening process, the steers in Lot I were fed approximately three-fourths of a full feed of ear corn during the first two months, after which they were given all that they would eat without waste until the close of the experiment. Lot II was not fed any corn until the beginning of the third month, when ear corn was added to the ration of silage and cottonseed meal in approximately the same amount as was fed to Lot I during the experiment. In each case, the ear corn was broken into two or three pieces to facilitate its consumption by the cattle. A sufficient number of hogs to prevent waste of grain which the cattle had failed to masticate and digest was allowed to run with the cattle.

Each group of steers was housed in an open shed, boarded up closely on three sides, with the south side open. Adjoining the shed was an open lot to which the steers had access at all times. The shed was kept bedded at all times. Water was supplied from galvanized iron troughs located outside the lots, one board being removed from the fence in order that the steers might have access to water at will.

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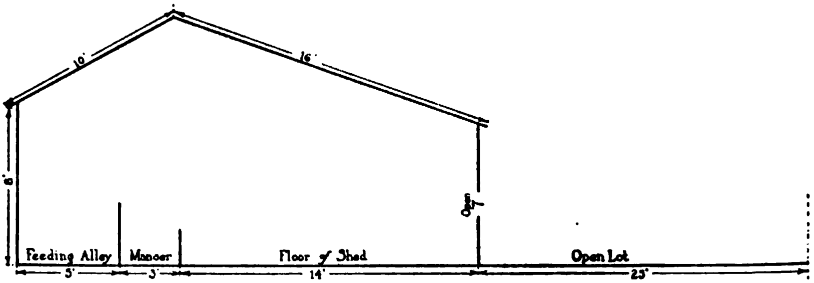
*Bulletin 112.

Plan of Feeding Shed.



Ear corn was fed at 6 A. M. and 5 P. M. Immediately after the cattle had consumed this, the corn silage was put in the manger and the allowance of cottonseed meal distributed over it in such manner that the proportion of cottonseed meal consumed by each animal would be determined by the amount of silage eaten.

Quality of Different Feeds.

The ear corn was quite variable, though it was about an average of that produced in the mountain valleys in the central portion of the state. It was free from mould and foreign material. The cottonseed meal was of excellent quality. The corn silage was grown on the college farm. On account of the drought which prevailed early in the summer, the stalks were not very heavy, and due to heavy rains in the fall, it contained a large amount of moisture when put into the silo. It was, however, of excellent quality, well preserved in a cypress stave silo. The accompanying table is presented to show the condition of the various feeds.

TABLE I.—Air-Dry Moisture in Feeds.*

	Dec. 19, 1911	Jan. 15, 1912	Feb. 12, 1912	Mar. 8, 1912	April 2, 1912	AVERAGE Dec. 1, '11 to April 19, '12
Ear corn	20.79	21.20	15.86	16.82	16.71	18.276
Cottonseed meal	9.19	7.14	7.57	6.74	7.33	7.594
Corn Silage	61.62	66.81	67.56	65.41	68.52	65.984
Corn silage and corn cobs refused	61.34	..	37.87	36.65	42.73	44.647

A study of the table showing the amount of different feeds offered and refused by the steers in each lot will show clearly that the dry feeds were limited to the amount which the cattle would consume. As the feeding period progressed, the steers would shell the corn from the cob and leave the cobs in the trough, so that the refuse silage contained some corn cobs. However, the chief object was to give each lot all of the silage that it would consume, so that a limited amount was left during each period. This was utilized for the feeding of other stock on the farm, hence was not an entire waste. It will be noticed that the steers in Lot I ate less silage as the amount of grain was increased, a fact which was even more striking in Lot II, when the addition of 1610 pounds of ear corn at the beginning of the third month caused a decrease in the amount consumed of 3224.75 pounds of silage.

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*Reported by Department of Experimental Agricultural Chemistry.

TABLE II.—Feeds Offered and Refused.

	LOT 1—12 STEERS				LOT 2—12 STEERS			
DATE	Offered			Refused	Offered			Refused
	Ear corn	Cotton-seed meal	Corn silage	Corn silage	Ear corn	Cotton-seed meal	Corn silage	Corn silage
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Dec. 1-15 ...	1330	275	5810	129.83		275	7475	48
Dec. 15-29	2080	336	4750	110.00		336	8350	98
Dec. 29-Jan. 12, 1912 ..	2315	336	4375	199.00		336	8400	67.50
Jan 12-26 ..	2235	336	4425	336.25		336	8400	93.00
Jan. 26-Feb. 9 ...	2420	336	4200	386.50	1610	336	5225	142.75
Feb. 9-23 ...	2650	336	3550	492.50	2340	336	4400	458.00
Feb. 23-March 8	2535	336	3370	450.00	2380	336	3420	330.75
March 8-22	2667.5	376.5	3360	437.75	2527.5	376.5	3360	312.50
March 22-April 4 ..	2660	499.5	3360	570.25	2520.0	499.5	3360	442.25
Total ..	20892.5	3167	37200	3112.08	11377.5	3167	52390	1992.75

There was little trouble caused by the method of feeding followed. At the beginning of the experiment, a few steers showed a tendency to scour, doubtless due to the change from hay and dry feed to silage. This condition lasted only a few days. after which the consistency of the droppings was normal. There were no steers "off feed" throughout the 18 weeks during which they were fed, although two individuals, one in each lot, seemed to be quite restless and would not come to the trough until after the others were satisfied. The temperature during January and February was decidedly below normal, the winter being the coldest on record at the College. A stave silo, 18 feet in diameter, in which the silage frequently froze at a distance of one to one and one-half feet from the wall was used. The silage was removed from the whole surface and that which was frozen, fed with the remainder without any attempt to thaw it before feeding. The weather was extremely unfavorable for silage feeding in open sheds, so that the results secured during this period should be entirely conclusive.

There was a very marked variation in the gains of the cattle throughout the winter, as shown by the accompanying table. The condition of the cattle seemed to be improving at all times, hence the variations may be due to a difference in fill at the time of weighing.

TABLE III.—Average Daily Gain Per Steer.

	Lot 1		Lot 2—No grain	
Dec. 1-15	2.70)	2.67	1.51)	2.24
Dec. 15-29	2.64)		3.07)	
Dec. 29-Jan. 12	1.97)	2.38	2.04)	2.53
Jan. 12-26	2.80)		3.03)	
Jan. 26-Feb. 9	1.84)	.44	3.03)	.66
Feb. 9-23	Loss .96)		Loss .07)	
Feb. 23-March 8	2.83)	2.24	2.63)	1.97
March 8-22	1.66)		1.32)	
March 22-Apr. 4	1.27	1.27	2.03	2.03
Dec. 1-Jan. 26 (56 days)	2.52	lbs.	2.40	lbs.
Jan 26-Mar. 22 (56 days)	1.33		1.30	
Dec. 1-Mar. 22 (112 days)	1.93		1.75	
Dec. 1-Apr. 4 (126 days)	1.86		1.85	

The small gains during the third month were due to the regular water supply being frozen, when it was necessary to drive the cattle out of their lots to another source of water. As it was only possible to do this once each day, there were many times when the cattle would refuse to drink, thus being off water for 48 hours. As this condition occurred in each lot, it does not affect the comparative results, but does materially reduce the rate of gain for the entire period and has unfavorable influence upon profits. The low rate of gain in Lot I during the last two weeks of the experiment was due to the length of time they were kept upon the same ration without any improvement in it. From this and other experiments, it seems necessary that rations be made concentrated toward the close of the finishing period in order that cattle may continue to make rapid gains until ready for the market. It would have been desirable in practice to have replaced the ear corn with shelled corn during this period, which would have caused a greater consumption of digestible nutrients above that required for maintenance. The results are, however, satisfactory, when the conditions under which the experiment was conducted and the method of feeding with light grain rations and without dry roughage of any sort are considered.

TABLE IV.—Average Amount of Feed and Dry Matter Consumed Per Head Daily.

DATE	LOT 1				LOT 2			
	Ear corn	Cotton-seed meal	Corn silage	Air-dry matter	Ear corn	Cotton-seed meal	Corn silage	Air-dry matter
	lbs	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Dec. 1-29	10.14	1.81	30.72	21.47		1.81	46.66	19.85
Dec. 29-Jan. 26	13.54	2.00	24.59	20.69		2.00	49.52	18.29
Jan. 26-Feb. 23	15.08	2.00	20.44	21.03	11.75	2.00	26.85	20.72
Feb. 23-Mar. 22	15.48	2.12	17.38	20.10	14.60	2.12	18.26	20.48
Mar. 22-Apr. 4	15.83	2.97	16.60	20.29	15.00	2.97	17.36	20.03
Dec. 1-Jan. 26 (1st 56 days)	11.85	1.90	27.65	21.08		1.90	48.09	19.07
Jan. 26-Mar 22 (2d. 56 days)	15.28	2.06	18.91	20.57	13.18	2.06	22.56	20.61
Jan. 26-Apr. 4 (last 70 days)	15.03	2.24	18.47	20.51	13.54	2.24	21.52	20.49
Dec. 1-Apr. 4 (126 days)	13.81	2.09	22.54	20.76	7.52	2.09	33.33	19.86

Table IV shows that there was a gradual increase in both the amount of ear corn and cottonseed meal fed to the cattle in Lot I, but that an increase in concentrates was accompanied by a decrease in the amount of silage used. The steers in this lot consumed a greater amount of dry matter during the first eight weeks of the feeding period than during the last ten weeks. The reverse was true in Lot II where ear corn was added to the ration during the latter period. The total amount of feed used by each steer in Lot

I was 24.8 bushels of corn, 41.6 pounds of cottonseed meal and 2,593.4 pounds of corn silage. In Lot II it was 13.5 bushels of corn, 41.6 pounds of cottonseed meal and 4,365.8 pounds of corn silage. As the gains made by each lot were almost identical, it may be said that 1,772.4 pounds of corn silage replaced 792.92 pounds of ear corn, or a ton of silage would replace 894.6 pounds of ear corn, which at 70c per bushel would give the silage a replacement value of $8.94 when substituted for ear corn under conditions prevailing in this test.

TABLE V.—Feed and Air-Dry Matter Required to Produce a Pound of Increase in Live Weight.

DATE	LOT 1				LOT 2			
	Ear corn	Cotton-seed meal	Corn silage	Air-dry matter	Ear corn	Cotton-seed meal	Corn silage	Air-dry matter
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Dec. 1-Jan. 26	4.68	.75	10.93	8.33		.79	20.20	7.99
Jan. 26-Apr. 4	11.65	1.69	13.97	15.52	7.00	1.58	15.25	14.44
Dec. 1-Apr. 4	7.43	1.12	12.13	11.17	4.06	1.13	17.99	10.72

Table V shows that the amount of feed and dry matter required to produce a pound of gain increases as the feeding period advances even though the ration is made more concentrated and has a higher energy value. This is probably due to the difference in the character of the gain. In the early stages there is a filling up of muscular tissue with water and proteids, but during the finishing period the gain is for the most part fat, which has a higher energy value than any other substance in the body. The results indicate that the heavier silage ration was more efficient in producing gain, though the general appearance of the cattle indicated that Lot I was fatter at the close of the test, hence the difference in efficiency was probably due to a difference in the kind of material put on the carcass. Neither of the two lots were sufficiently finished to command the attention of buyers who look for fancy beef, but were classified as "handy-weight" steers such as are in strong demand at all times. A higher finish would have required a much longer feeding period and a much more expensive ration.

Shipment and Sale of Cattle.

The cattle were loaded on cars at State College Saturday morning, April 6, 1912, and shipped to Pittsburgh where they were sold as one lot on Monday, April 8, 1912. The following table gives in detail the expenses incurred in shipment.

TABLE VI.—Shipment, Sale and Killing Test of Cattle.

	LOT 1 (12 Steers)	LOT 2 (12 Steers)
Home weight (not shrunk)	13,425 lbs.	13,360 lbs.
Sale weight in Pittsburgh	12,720 "	12,630 "
Dressing percentage	57.08 %	57.56 %
Weight of hides	800 lbs.	777 lbs.
Edible fat	472 "	522 "
Rough fat	60 "	60 "
Selling value at yards	$ 7.20	$ 7.00
Total receipts	$915.84	884.10
Expenses of shipping:		
Freight	$ 24.06	$ 23.85
Commission	7.20	7.20
Feed and yardage	9.00	8.70
Total	$ 40.26	$ 39.75
Net receipts	875.58	844.35
Selling value in feed lots without shrinkage	6.52	6.32

The shrinkage in transit was practically the same in each lot and was very much heavier than in former shipments between the two points. The cattle were delayed enroute, due to tracks

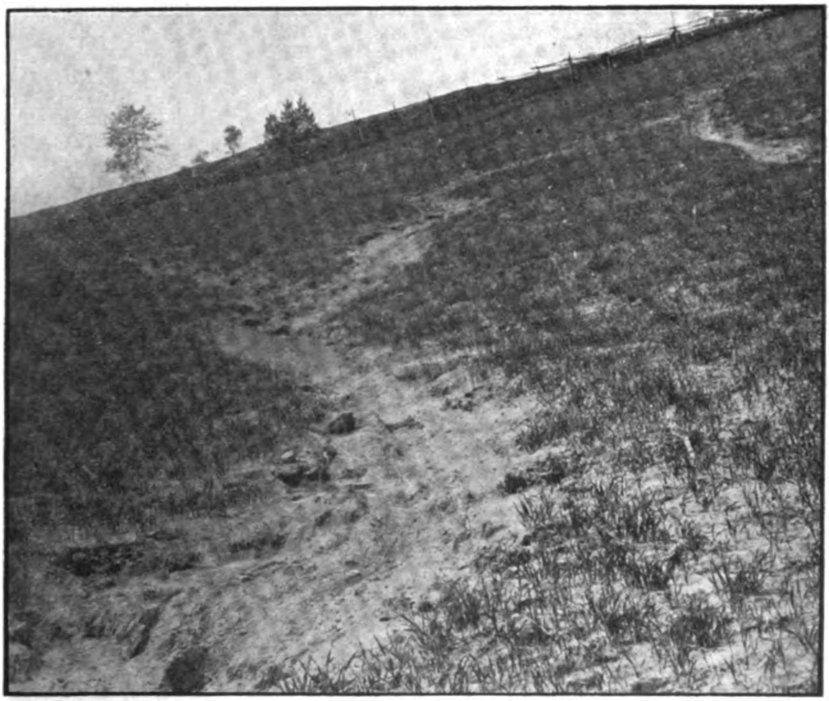

Figure 3. Soil erosion due to a deficiency of humus. Such hillsides should be seeded to permanent pasture.

being blockaded, and as the car was heavily loaded this fact possibly caused an excess shrinkage. The morning of April 8, the weather was very damp, raw and disagreeable, which materially affected the fill, and on account of securing experimental weights the selling was delayed until 11 o'clock during which time most of the fill had been lost. These factors should be taken into consideration when shrinkage is considered. The dressing percentage in the two lots was quite similar, though the carcasses in Lot I were slightly more attractive, being smoother and more evenly covered.

SUMMARY.

Steer Feeding Experiment During the Winter of 1911-12.

	LOT 1 (12 Steers)	LOT 2 (12 Steers)
Length of feeding period	126 days	126 days
Initial value per cwt. in feed lots	$5.07	$5.07
Initial weight	10,615 lbs.	10,560 lbs.
Final Weight	13,425 "	13,360 "
Total gain	2,810 "	2,800 "
Average daily gain per steer	1.86 "	1.85 "
Total feed consumed:		
Ear corn	20,892.5 "	11,377.5 "
Cottonseed meal	3,167 "	3,167 "
Corn silage	34,087.9 "	50,397.2 "
Air-dry matter consumed	31,403.4 "	30,037.9 "
Average daily feed per steer:		
Ear corn	13.81 "	7.52 "
Cottonseed meal	2.09 "	2.09 "
Corn silage	22.54 "	33.33 "
Average air-dry matter consumed per steer daily	20.76 "	19.86 "
Total cost of feed*	$319.25	$252.64
Cost of feed per 100 lb gain*	11.36	9.02
Total cost of cattle and feed	857.43	788.03
Cost per cwt. at close of expt.	6.39	5.90
Selling value per cwt. in Pittsburgh	7.20	7.00
Selling value at home	6.52	6.32
Net receipts	875.58	844.35
Total profit*	18.15	56.32
Price received per bushel of corn fed after paying for other feeds*	.761	$1.046
Price received per ton for silage after paying for other feeds*	4.65	5.73

*Based upon ear corn at 70c per bushel: cottonseed meal at $32.00 per ton and corn silage at $3.50 per ton.

The summary of the experiment shows that the feeding of corn silage as the only roughage resulted in satisfactory gains in each lot, and that while there was a profit in feeding ear corn throughout the entire feeding period, a greater profit was secured when light plain feeders averaging 880 pounds at the beginning of the feeding period were carried for two months on a ration consisting entirely of corn silage, followed with a grain ration toward the end of the feeding period. In estimating profits, full market value has been allowed for all feeds so as to cover the labor of feeding. No credit is given for manure or for pork produced from the droppings of the cattle. It is generally estimated that hogs following steers will gain 2 pounds for each bushel of ear corn fed to cattle. If this additional increase were allowed, the profit in Lot I would be increased $47.84, and in Lot II, $26.80 over and above that indicated in the summary. A record of bedding used and manure produced in Lot I was kept, which shows that 25,675 pounds of sawdust and 2,762 pounds of straw were used for bedding.

The manure weighed out amounted to 101,560 pounds. Allowing $1.00 per ton for sawdust (the cost delivered at barn), $8.00 per ton for straw and $1.50 per ton for manure, there was an additional profit of $31.24 to that made from direct feeding of steers and production of pork from droppings in Lot I during the 126 days of feeding. This shows that in cattle feeding, the profits secured from the by-products of feed lots may amount to more than the direct financial gain on the cattle. The test shows conclusively that silage can be used as roughage even in the coldest of winters when fed in an open shed; that there was a considerable saving of corn by the exclusive use of silage during the first part of the feeding period and that the value of feeds utilized in the production of beef during the winter of 1911-12 was much greater than their market value. The results of this and other tests at The Pennsylvania State College and Experiment Station indicate that beef can be finished profitably in the state, where due attention is paid to the growth of crops equally adaptable to the soil and to feeding purposes.

WINTERING BEEF BREEDING COWS

Selection of rations on which beef cattle may be successfully maintained during the winter at a comparatively low cost is one of the most important problems before live stock producers. In the past, the feeders of beef cattle have depended upon shipping cattle from western markets for finishing on eastern grown feeds, as two-year-old steers could be purchased for less than the cost of producing them locally. The large ranges of the west are being divided into smaller farms and their supply of cattle is diminishing while the demand is continually increasing. The result of this will be the production of feeding cattle on lands that are especially adapted to the business, capable of producing grass in abundance, well supplied with water and shade and of such topography or distance from markets that they cannot profitably be utilized for the continuous production of cereal crops.

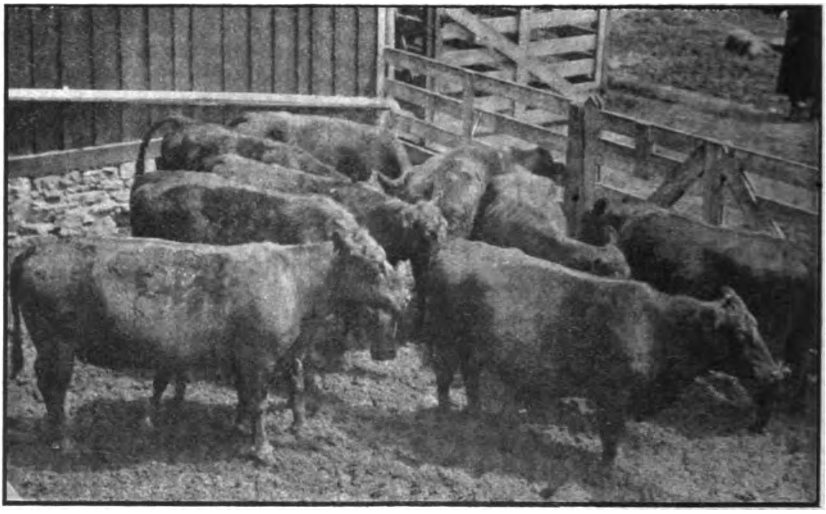

Figure 4. Group of Angus cows used in silage experiment. Photograph taken at close of feeding period.

There are large areas in almost every section of Pennsylvania, which, although too steep to plow, are especially adapted to the growth of pasture grasses and in every way favorable to the production of beef. In many of the counties where timber has been cut off, the hillsides might as well be producing grass as brush and weeds. The problem after the pastures have been established is to grow a sufficient amount of roughage to carry cattle through winter at a minimum of expense. The demand for hay has increased so rapidly during the past few years that many farmers would sell it rather than feed it to cattle, were it not for the fact that they realize the necessity of keeping roughage on the farm in order to maintain the fertility of the soil.

This experiment was undertaken to find some feed that would produce a larger amount of food nutrients per acre than hay, equally as well adapted to the feeding of breeding cattle, supplemented with a minimum amount of concentrated feeds which would furnish the digestible nutrients not provided by the farm-grown crop. Corn silage was selected as most nearly meeting these conditions. It is adaptable to a wider range of soil conditions than any other crop except grass, it produces a large amount of food nutrients per acre, is palatable, succulent, easily grown, harvested with comparative ease and can be stored at less expense for buildings than any other forage crop. In addition to these advantages, there is no other form in which the corn crop will be entirely consumed by livestock, thus it increases in value by being placed in the silo. Cottonseed meal was used as a supplement because

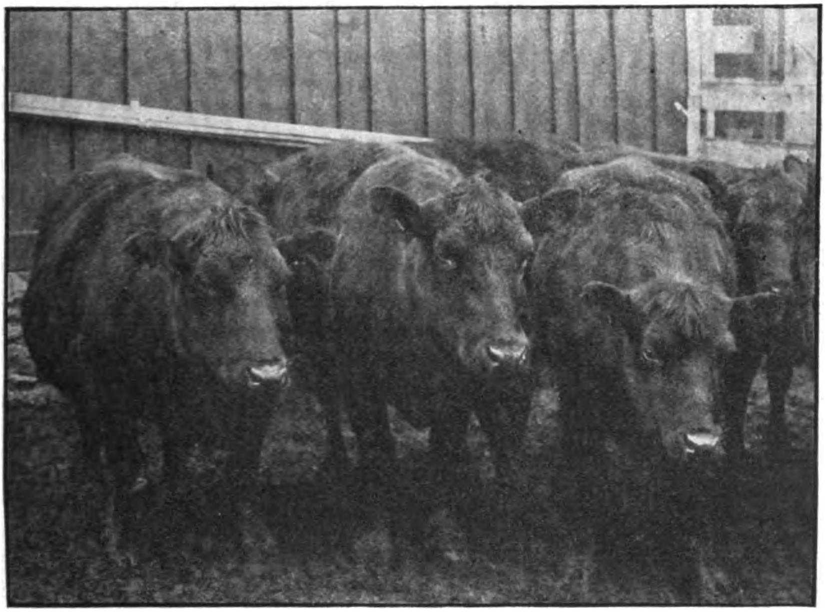

Figure 5. Low-set Blocky Aberdeen Angus cows suitable for the production of market topping steers.

of the fact that protein, in which corn silage is quite deficient, could be secured in this form cheaper than from any other source and because of the large percentage of protein that could be fed in very small quantities, thus reducing the expense for transporation and labor in feeding. Previous investigation has also shown that the laxative tendency caused by heavy feeding of succulent feeds is materially reduced by the addition of cottonseed meal to the rations.

The Plan of the Experiments.

Ten pure-bred Shorthorn cows were purchased in Mercer County, Pennsylvania, and ten pure-bred Aberdeen-Angus cows were selected from the College herds to be used in the test.The Shorthorns were in very thin flesh, having been kept entirely on grass during the summer and fall of 1911. On account of the deficiency in rainfall, pastures were extremely short, hence the cattle had lost flesh during the grazing season. They had produced calves the preceding year, but were not bred at the time of purchase. The Angus cows had raised calves during the summer and were re-bred to produce another crop during the winter and spring. Because of the better fall pasture in the central part of the state, they were in much higher condition at the beginning of the test. Each group of ten cows was allowed to run loose under an open shed used for steer feeding purposes, adjoining which was an open lot. The floor space in each shed, exclusive of that occupied by mangers and feeding alley, was 420 square feet. The area of the open lot was 780 square feet. The cattle were confined in these lots from the beginning of the experiment on December 1, 1911, until the close, April 19, 1912, a period of 140 days. While the housing and shelter were ample, as shown by results secured, a greater area in the open lot would be desirable.

Method of Feeding.

The corn silage was removed from the silo twice daily and fed to the cows directly after weighing, in such quantities that there would be none left in the mangers one hour after feeding. Cottonseed meal was fed once daily at the rate of one pound to each cow. This was distributed over the entire amount of silage in order that the amount consumed would be determined by the amount of silage. One lot of cows was bedded with sawdust, the other with straw. Bedding was distributed at such intervals as the condition of sheds and lots justified.

TABLE I.—Showing Feeds Fed and Refused.

DATE	10 Shorthorn Cows			10 Aberdeen Cows		
	Cotton-seed meal	Corn silage	Refused silage	Cotton-seed meal	Corn silage	Refused silage
Dec. 1-15, 1911	140	8000	181.00	140	8700	74.58
Dec. 15-29	140	7700	.....	140	7775	....
Dec. 29-Jan. 12, 1912 ..	140	7700	.....	140	7700	....
Jan 12-26	140	8400	9.25	140	8400	....
Jan. 26-Feb. 9	140	8400	11.50	140	8400	19.00
Feb. 9-23	140	8400	8.00	140	8400	57.00
Feb. 23-Mar. 8	140	8400	33.50	140	8400	130.75
Mar. 8-22	140	8400	54.75	140	7550	309.75
Mar. 22-Apr. 5	140	8400	87.25	140	7000	....
Apr. 5-19	140	8400	15.50	140	7000	135.75
	1400	82200	400.75	1400	79325	726.83

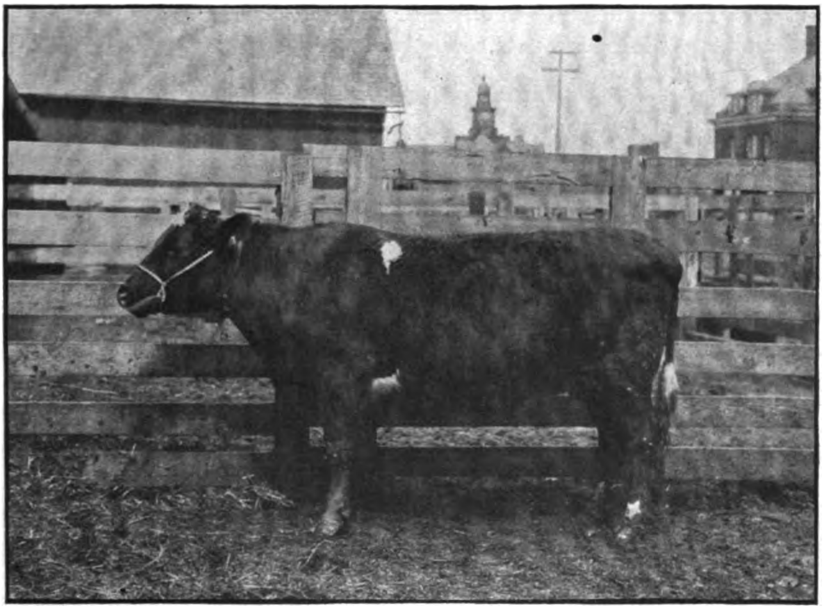

Figure 6. Shorthorn cow used in silage experiment. Note high condition at end of feeding period.

Table I shows that the Shorthorn cows did not consume quite as much silage during the first two weeks as did the Angus, due to the fact that they had never been fed from the silo previously, while the Angus cows had received silage in their ration the preceding winter. After the first six weeks, however, both lots were fed at the rate of 60 pounds per head daily, which proved to be ample for satisfying their appetites. This amount was fed to the Shorthorn cows throughout the remainder of the winter, with less than 1% waste. During the latter part of February, however, the Angus cows refused to eat the full allowance, although they were increasing in weight and some of them were suckling calves. This result confirms that of preceding tests at this station with steers fed largely on roughage, when thin they will make very rapid gains, but as they improve in condition, their consumption of feed decreases, finally reaching a point where the appetite for roughage is only sufficient for maintenance. It is probable that a decrease in food consumption would also have been noted in the Shorthorn lot if the test had been continued through a longer period of time. At the close of the test, both lots of cows were turned on pasture without grain and had made slight gains after two months of grazing, at which time this report was written.

As beef cattle are maintained largely for the purpose of producing manure to be used in increasing the yield of crops, a record of the amount of bedding and manure produced in the Shorthorn lot was secured. During the 140 day feeding period, 9851 pounds of straw were used in bedding the ten cows, and from this lot 88,405 pounds of manure were removed. It would require, under these conditions, the straw from approximately one acre of small grain to bed each individual and this would result in the production of 8,840 pounds of manure. A larger amount of straw could have been utilized to advantage where cows were closely confined as in this test, though under farm conditions where the cows were permitted to run in pasture during suitable weather, the required amount of bedding could be materially reduced.

Summary of Experiment in Wintering Twenty Beef Breeding Cows.

Length of experiment	140	days
Initial weight of 20 cows	21,438.7	lbs.
Final weight of 20 cows	24,729.66	"
Total gain	3,290.84	"
Average daily gain per cow	1.17	"
Total feed consumed		
Corn silage	16,039.75	"
Cottonseed meal	2,800.00	"
Average daily feed per cow		
Corn silage	57.64	"
Cottonseed meal	1.00	"
Cost of feeding 20 cows		
Corn silage @ $3.50 per ton	$280.69	
Cottonseed meal @ $30.00 per ton	42.00	
Total	$322.69	

Average cost of feed per cow	16.13
Bedding used per cow:	
985 lb. wheat straw @ $8.00 per ton.	3.94
Labor in feeding	2.00
Total expenditure	22.07
Value of manure per cow:	
8840 lbs. @ $1.50 per ton	6.63
Value of Increase in weight:	
164.5 lb. @ 5c per lb.	8.22
Total value	14.85
Net cost of wintering cow	8.22

The data presented in the summary is based upon prevailing local prices of feeds throughout the state during the winter of 1911-

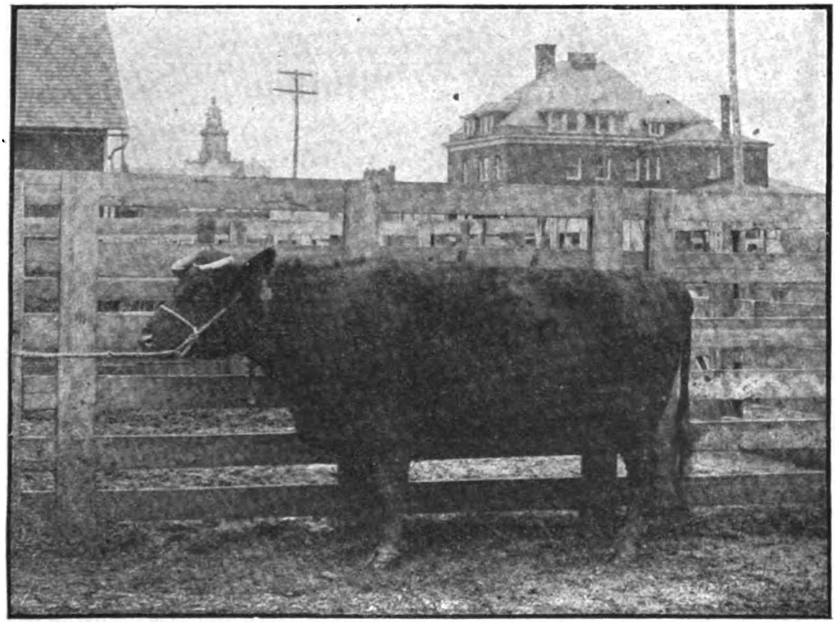

Figure 7. A typical Shorthorn cow suitable for the production of feeding steers.

12. Corn silage is valued at $3.50 per ton, which is equivalent to 70c per bushel for corn, thus allowing a very material profit in its production before charging it as feed. It required four tons of silage to winter each cow, which is equivalent to one-half of an acre when corn yields 40 bushels per acre or one-third of an acre when the land will produce a 60 bushel corn crop. The weather conditions during the progress of the test were the most severe of any ever recorded at the local weather bureau, the temperature frequently falling be-

low zero and at times as low as 23 degrees below. The results were thus secured under the most unfavorable rather than favorable circumstances and should be easily duplicated in the future. As the cows have not lost in weight on pasture without grain from the 19th of April to the 29th of June, it is reasonable to suppose that they will maintain their weight throughout the summer where ample range is provided to insure an abundance of grass throughout the season. With pasture at $1.00 per head per month, the total cost of maintenance throughout the year will be $15.22 per head, or with pasture at $2.00 per head it will amount to $22.22, either of which estimates allow ample profit from the growing of crops and a reasonable rate of interest on land kept in permanent pasture. Only a few of the cows have produced calves during the progress of the experiment. The oldest of these weighed 520 pounds when six months of age, which, at prevailing beef prices, would allow a profit of from $10 to $15 on the cost of keeping the cow. This system of farming will permit a uniform distribution of labor throughout the year, a maximum profit in the production of crops, the maintenance of soil fertility at a minimum expense and the utilization of all rough and broken land capable of producing grass. It will also solve the problem of securing feeding cattle at less cost than they can be purchased on the central markets of the country, eliminate loss in transit and insure a better bred lot of cattle in those sections of the state where the system is followed. The state of Pennsylvania is especially adapted to the production of grass and silage, which are the two crops considered in this experiment. The local demand for beef is greater than in any other section of the country, which should insure profitable production of beef within its borders through a long series of years.

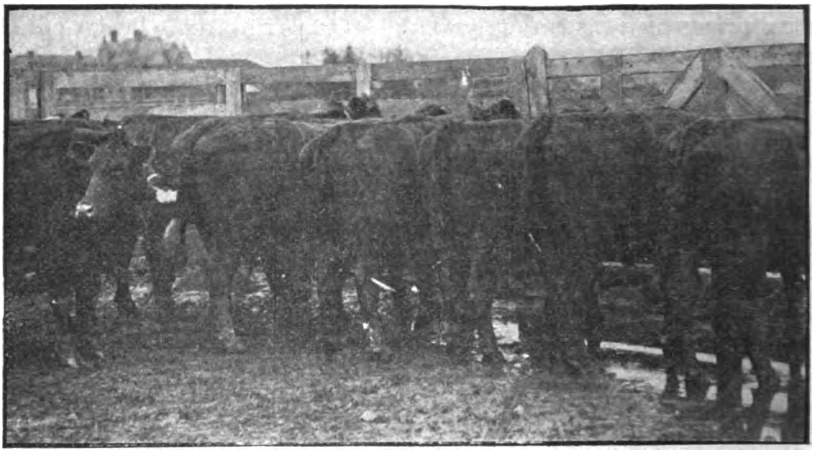

Figure 8. Group of Shorthorn cows at close of silage feeding experiment.

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Agricultural Experiment Station

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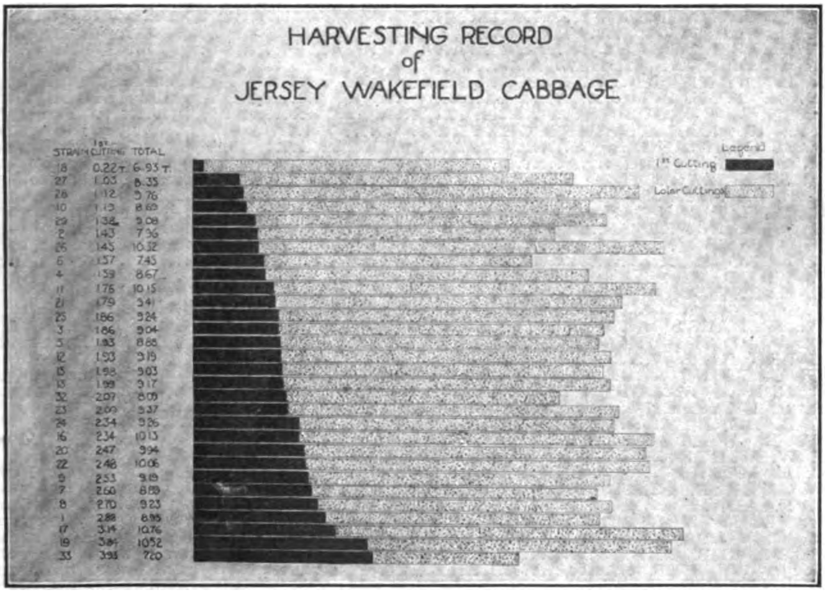

STRAIN TESTS OF CABBAGE

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
DECEMBER, 1912.

AGRICULTURAL EXPERIMENT STATION
THE PENNSYLVANIA STATE COLLEGE

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The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 119

STRAIN TESTS OF CABBAGE*

BY C. E. MYERS

Historical Note.

In the spring of 1908, an experiment was instituted by the Department of Horticulture to determine the relative value of cabbage seed of the same variety from different sources. A preliminary test was made of Jersey Wakefield, the seed of which was secured from twenty-four sources and the results of which test were published in Bulletin 96 of this Station.

This preliminary work showed the desirability of making the test more comprehensive and in 1909 it was made to include twenty-nine strains of Jersey Wakefield, twenty-four of Charleston Wakefield, twenty-three of Early Spring, twenty-four of Early Summer, thirty-five of Danish Ballhead, twenty-two of Succession, twenty-two of Flat Dutch, twenty of Surehead, and eleven of Volga.

Soil and Fertilization.

The tests have been conducted on the Experiment Station farm, the soil of which is Hagerstown clay loam and is naturally fertile. This fertility has been supplemented by the use of barnyard manure and commercial fertilizer. However, the fertilization has not been excessive. the aim being to supply normal conditions for growth. In each instance the tests have been made under conditions as nearly uniform as possible. For the years 1910 and 1911, checks have been used and corrections have been made for probable variations in soil fertility. Thus any differences in character or yield are attributed to differences in the inherent productive properties of the seed.

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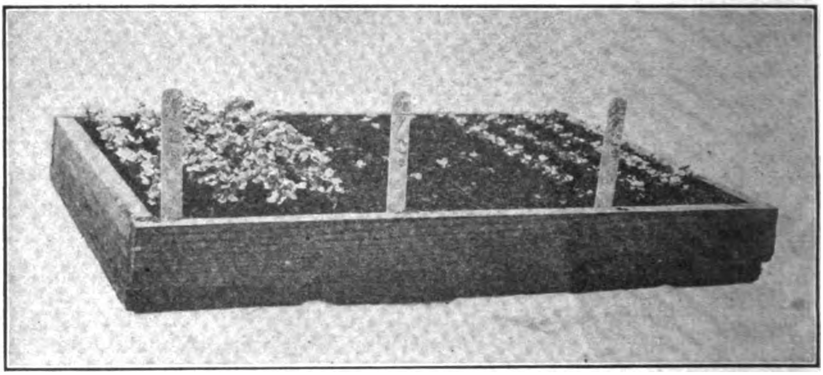
*The results of these experiments include about 350 pages which will be published in full in the Annual Report for 1911-12. The Report may be secured on request from members of the Assembly or Senate, Harrisburg, Pa.

Factors Considered in the Experiment.

The first factor of importance revealed by the experiments is that of the variation in germination. Generally considered. this subject should not be of especial importance so long as a fair percentage of the seed germinates. The standard for cabbage is ninety per cent and in most of the strains the germination has been quite satisfactory. In a few, however, it was very weak and seed tested the first year it was received showed a viability of not more than ten per cent.



Variation in Germination of Strains of Jersey Wakefield.

This is far too low and would prove a great disappointment were it planted without the fact being known. It is well worth while to make a germination test of the seed previous to the time of sowing. By so doing, the rate of sowing may be regulated so as to secure a desirable stand of plants. Whenever possible the test should be made in the soil.

Trueness to name and type is perhaps one of the most important factors in relation to this crop. Not infrequently markets demand certain types, and failure to produce a crop which conforms to the type desired is accompanied by financial loss.

In the conducting of this experiment several facts of interest have been noted. In most instances the strain was fairly true to name and type but in few instances were these factors as uniformly perfect as might be desired. Several of the strains were decidedly untrue to type yet showed a general resemblance to the variety. This has been especially noticeable in the test of Jersey Wakefield and Early Spring. In some of the tests the strain was a variety other than that for which

Relative value of seed of same
variety from different sources
Early Jersey Wakefield 1908 seed
PROJECT 25B.
11a
Check

Variation in Earliness and Trueness to Type.

it was purchased. This was particularly noticeable in the test of Early Spring, of which two were Early Summer, one Jersey Wakefield, and others considerably mixed. In the test of the late varieties in a few instances the strain was not true to name. These irregularities show the need of greater care being exercised on the part of seedsmen.

Test of the Early Varieties.

Perhaps the factor of most importance has been the variation in earliness of maturity and yield. The following table gives a summary of the test of Jersey Wakefield for the years of 1909, 1910, 1911.

Table I.—General Average of the Test of Jersey Wakefield Cabbage for the Years 1909, 1910 *and* 1911.

Record No.	SOURCE	Average weight of heads pounds	Average yield per acre, first cutting	Average corrected yield per acre*
1.	Alexander Seed Co., Augusta. Ga.	1.66	2.88T	8.95 T
2.	W. C. Beckert, Pittsburgh, Pa.	1.52	1.43	7.96
3.	J. Bolgiana & Son, Baltimore, Md.	1.60	1.86	9.04
4.	H. W. Buckbee, Rockford, Ill.	1.46	1.59	8.67
5.	W. Atlee Burpee, Philadelphia, Pa.	1.62	1.93	8.88
6.	H. A. Dreer, Philadelphia, Pa.	1.45	1.57	7.45
7.	D. M. Ferry & Co., Detriot, Mich.	1.38	2.60	8.89
8.	The Germain Seed Co., Los Angeles, Cal.	1.57	2.73	9.23
9.	Peter Henderson & Co., New York, N. Y.	1.41	2.53	9.19
10.	Holmes Seed Co., Harrisburg, Pa.	1.44	1.19	8.69
11.	Kansas Seed House, Lawrence, Kansas.	1.72	1.76	10.15
12.	Leonard Seed Co., Chicago, Ill.	1.43	1.93	9.19
13.	Livingston Seed Co.. Columbus, Ohio. ..	1.35	1.99	9.17
14.	Mo. Valley Seed Co., St. Joseph, Mo. ...	1.69	***	***
15.	Moore & Simon, Philadelphia, Pa.	1.34	1.98	9.03
16.	Northrup, King & Co., Minneapolis, Minn	1.54	2.34	10.13
17.	W. W. Rawson, Boston, Mass.	1.64	3.14	10.76
18.	W. P. Stokes, Philadelphia, Pa.	1.09	0.22	6.93
19.	J. M. Thorburn, New York, N. Y.	1.67	3.84	10.52
20.	Webber & Don, New York, N. Y.	1.47	2.47	9.94
21.	T. W. Wood & Son, Richmond, Va. ...	1.47	1.79	9.41
22.	Jas. Vick's Sons, Rochester, N. Y.....	1.56	2.48	10.06
23.	H. F. Michell, Philadelphia, Pa.........	1.49	2.09	9.37
24.	Robinson Seed & Plant House, Dallas, Tex.	1.52	2.34	9.26
25.	Texas Seed & Floral Co., Dallas Tex.	1.52	1.86	9.24
26.	W. F. Allen, Salisbury, Md.	1.50	1.45	10.32
27.	Missouri Seed Co., Kansas City, Mo. ..	1.41	1.03	8.35
28.	M. Garrahan, Kingston, Pa.	1.53	1.12	9.76
29.	Wm. Ewing, Montreal, Canada.	1.32	1.38	9.08
**32.	Chas H. Lilly, Seattle, Wash.	1.09	2.07	8.09
**33	A. G. Tillinghast, La Conner, Wash. ..	0.95	3.93	7.20

* 2 year Average.

** 1 year test.

*** Too few plants to estimate yield.

A study of the table will show interesting variation with respect to each of the characters under consideration. It will be seen that the average weight of head varied from 0.95 to 1.72 pounds. In most instances, heads weighing less than one and one-fourth pounds are not desirable unless they mature very early. It is probable that the yield per acre at the first cutting may be considered as one of the most important factors. As a general practice the most profitable part of the crop is that which matures early. This feature is also desirable in that it permits of the ground being utilized for other purposes. A reference to the above table will show that the yield per acre at the first cutting for the thirty-one strains varied from 0.22 to3.84 tons. Likewise, the corrected yield per acre† varied from 6.93 to 10.76 tons per acre. Thus there was a difference of 3.83 tons per acre in favor of the better strain.

The next table shows in a similar way a summary of the test of Charleston Wakefield.

Table II.—General Average of the Test of Charleston Wakefield Cabbage for the Years 1909, 1910 *and* 1911.

Record No.	SOURCE	Average weight of heads pounds	Average yield per acre, first cutting	Average corrected yield per acre*
1.	Alexander Seed Co., Augusta, Ga.	1.92	3.79T	9.62T
2.	W. C. Beckert, Pittsburgh, Pa.	1.82	3.98	9.27
3.	J. Bolgiano & Son, Baltimore, Md.	1.64	2.73	8.17
4.	H. W. Buckbee, Rockford, Ill.	1.69	3.13	8.76
5.	W. Atlee Burpee, Philadelphia, Pa.	1.65	3.92	9.02
6.	H. A. Dreer, Philadelphia, Pa.	1.65	3.84	9.17
7.	D. M. Ferry, Detroit, Mich.	1.84	3.29	11.23
8.	Germain Seed Co., Los Angeles, Cal. ..	1.78	6.46	11.53
9.	Peter Henderson & Co., New York, N. Y.	1.69	3.02	9.81
10.	Holmes Seed Co., Harrisburg, Pa.	1.69	3.66	10.52
11.	Kansas Seed House, Lawrence, Kansas.	1.97	3.68	11.05
12.	Leonard Seed Co., Chicago, Ill.	1.66	3.94	9.79
13.	Livingston Seed Co., Columbus, Ohio. ..	1.68	1.99	8.07
14.	Mo. Valley Seed Co., St. Joseph, Mo. ..	1.75	3.46	10.33
15.	Moore & Simon, Philadelphia, Pa.	1.68	1.79	9.39
16.	Northrup, King & Co., Minneapolis, Minn	1.79	4.95	10.94
17.	W. W. Rawson, Boston, Mass.	1.69	6.00	9.99
18.	W. P. Stokes, Philadelphia, Pa.	1.57	3.78	10.28
19.	J. M. Thorburn, New York, N. Y.	1.64	4.75	9.93
20.	Webber & Don, New York, N. Y.	1.68	5.79	10.69
21.	T. W. Wood & Son, Richmond, Va.	1.74	5.19	10.06
22.	Jas. Vick's Sons, Rochester, N. Y.	1.65	4.43	10.31
23.	H. F. Michell & Co., Philadelphia, Pa. ..	1.73	4.77	11.02
24.	Robinson Seed & Plant House, Dallas, Tex.	1.71	5.35	10.39

* 2 year Average.

A study of this table shows that the variation in yield per acre at the first cutting ranged from 1.79 to 6.46 tons. This difference of 4.67 tons per acre is a matter of considerable importance from a commercial standpoint. Likewise, the corrected yield varied from 8.07 to 11.53 tons, making a difference of 3.46 tons per acre in favor of the better strain.

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†The corrected yield per acre is given as the measure of crop production. In determining it, attention is given to probable variation in soil fertility and corrections made for the same. In the opinion of the writer it most accurately expresses the crop producing property of a strain. The method of determination is given in full in the Annual Report.

The next table gives the record of the test of Early Spring.

Table III.—General Average of the Test of Early Spring Cabbage for the Years 1909 *and* 1910.

Record No.	SOURCE	Average weight of head, pounds	Average yield per acre, first cutting	Average corrected yield per acre*
1.	Alexander Seed Co., Augusta, Ga.	2.29	7.94T	12.35T
2.	W. C. Beckert, Pittsburgh, Pa.	1.79	6.75	9.70
3.	J. Bolgiano & Son, Baltimore, Md.	1.70	5.50	8.63
4.	H. W. Buckbee, Rockford, Ill.	2.51	5.50	13.70
5.	W. Atlee Burpee, Philadelphia, Pa.	2.55	5.39	13.27
6.	H. A. Dreer, Philadelphia, Pa.	2.22	1.59	10.82
7.	D. M. Ferry & Co., Detroit, Mich	2.25	8.49	9.76
8.	Germain Seed Co., Los Angeles, Cal. ..	2.77	4.26	11.35
9.	Peter Henderson & Co., New York, N. Y.	2.23	8.13	11.15
10.	Holmes Seed Co., Harrisburg, Pa.	1.85	1.87	10.47
11.	Kansas Seed House, Lawrence, Kansas.	2.14	7.19	12.10
12.	Leonard Seed Co., Chicago, Ill.	2.16	7.44	12.20
*13	Livingston Seed Co., Columbus, Ohio.......	1.74	7.00	10.10
14.	Mo. Valley Seed Co., St. Joseph, Mo....	***	***	***
15.	Moore & Simon, Philadelphia, Pa.	1.83	5.69	12.78
*16.	Northrup, King & Co., Minneapolis, Minn.	1.83	9.87	10.42
17.	W. W. Rawson, Boston, Mass.	2.50	8.86	11.97
18.	W. P. Stokes, Philadelphia, Pa.	2.61	11.56	15.43
19.	J. M. Thorburn, New York, N. Y.	2.65	10.94	15.00
20.	Webber & Don, New York, N. Y.	1.89	8.41	10.75
21.	T. W. Wood & Son, Richmond, Va.	2.01	3.26	10.57
22.	Jas. Vick's Sons, Rochester, N. Y.	1.79	5.50	6.60
29.	Wm. Ewing, Montreal, Canada.	2.66	9.88	14.17

*Computed for one year only.

*** Too few plants to estimate yield.

A study of this table shows very important differences as regards earliness. It will be seen that the yield at the first cutting varied from 1.59 to 11.56 tons. This difference of 9.97 tons per acre is a matter of considerable importance. It will also be seen that the corrected yield per acre varied from 6.60 to 15:43 tons, making a difference of 8.83 tons per acre in favor of the superior strain. The trueness to type of the better yielding strain was also very pronounced.

Table IV shows the summary of the test of Early Summer.

Table IV.—General Average of the Test of Early Summer Cabbage for the Years 1909, 1910 *and* 1911.

Record No.	SOURCE	Average weight of head, pounds	Average yield per acre, first cutting	Average corrected yield per acre*
1.	Alexander Seed Co., Augusta, Ga.	2.06	7.75 T	11.43 T
2.	W. C. Beckert, Pittsburgh, Pa.	2.00	6.54	11.15
3.	J. Bolgiano & Son, Baltimore, Md.	1.69	3.92	8.86
4.	H. W. Buckbee, Rockford, Ill.	2.09	7.42	12.88
5.	W. Atlee Burpee, Philadelphia, Pa.	1.67	4.79	9.72
6.	H. A. Dreer, Philadelphia, Pa.	1.73	5.18	9.10
7.	D. M. Ferry & Co., Detroit, Mich.	1.74	6.83	10.04
8.	Germain Seed Co., Los Angeles, Cal.	1.76	4.88	9.66
9.	Peter Henderson & Co., New York, N. Y.	1.78	6.25	9.84
10.	Holmes Seed Co., Harrisburg, Pa.	1.79	4.57	10.54
11.	Kansas Seed House, Lawrence, Kansas.	1.71	6.11	11.15
12.	Leonard Seed Co., Chicago, Ill.	1.65	4.54	10.09
13.	Livingston Seed Co., Columbus, Ohio.	1.82	4.75	10.15
14.	Mo. Valley Seed Co., St. Joseph, Mo.	1.75	5.23	10.46
15.	Moore & Simon, Philadelphia, Pa.	1.72	5.70	8.92
16.	Northrup, King & Co., Minneapolis, Minn.	1.68	3.62	9.54
17.	W. W. Rawson, Boston, Mass.	1.72	4.75	9.29
18.	W. P. Stokes, Philadelphia, Pa.	1.82	5.67	8.81
19.	J. M. Thorburn, New York, N. Y.	1.95	4.58	9.46
20.	Webber & Don, New York, N. Y.	1.78	3.72	9.66
21.	T. W. Wood & Son, Richmond, Va.	1.82	4.31	10.98
22.	Jas. Vick's Sons, Rochester, N. Y.	1.94	5.08	10.80
23.	H. F. Michell & Co., Philadelphia, Pa.	2.00	4.46	12.37
24.	Robinson Seed & Plant House, Dallas, Tex.	2.28	8.42	14.96

*Computed for two years.

The yield per acre at the first cutting varied from 3.62 to 8.42, while the corrected yield per acre varied from 8.81 to 14.96 tons. This difference of 6.15 tons per acre is less pronounced than in the test of Early spring, yet it is worthy of consideration.

Late Varieties.

The test of late varieties has shown less pronounced differences in regard to variabilitiy from type than was noted in the test of the early varieties, although some strains were not true to name and others were considerably mixed.

The difference in yield in many cases has been quite pronounced. The following table gives the average of the test of Danish Ballhead.

Table V.—General Average of the Test of Danish Ballhead Cabbage for the Years 1909, 1910 *and* 1911.

Record No.	SOURCE	Remarks by Seedsmen	Average weight of head pounds	Average corrected yield per acre**
1a	Francis Brill, Hempstead, N. Y.	Home Grown. ..	3.25	20.56 T
1b	Francis Brill, Hempstead, N. Y.	1906 Seed	3.33*	***
2	H. W. Buckbee, Rockford, Ill.	"Very Choice Strain." ...	2.79	6.19
3a	W. Atlee Burpee, Philadelphia, Pa.	Danish Grown .	3.12	15.39
*3b	W. Atlee Burpee, Philadelphia, Pa.		3.28	18.82
4	Darling & Beahan, Petosky, Mich.		2.94	15.80
5	H. A. Dreer, Philadelphia, Pa.		2.55	11.86
6	Wm. Ewing, Montreal, Canada.	Danish Cannon Ball	2.41	11.34
7a	D. M. Ferry & Co., Detroit, Mich.	Commercial Am. Grown	2.30	10.67
7b	D. M. Ferry & Co., Detroit, Mich.	No. 30042	2.44	6.98
7c	D. M. Ferry & Co., Detroit, Mich.	Imported No. 44011	2.70	11.65
8a	Jos. Harris, Coldwater, N. Y.	"Tall Stem"	3.23	17.45
8b	Jos. Harris, Coldwater, N. Y.	"Short Stem" ..	2.52	13.14
9a	Harvey Seed Co., Buffalo, N. Y.	"Big Tall Stem"	2.33	11.71
9b	Harvey Seed Co., Buffalo, N. Y.	"Imported Short Stem"	2.90	15.35
10	Peter Henderson & Co. New York, N.Y.	....	2.87	14.89
11	S. M. Isbell & Co., Jackson, Mich.	....	2.91	***
12	Leonard Seed Co., Chicago, Ill.	"Leonard Strain"	2.46	13.91
13	W. H. Maule, Philadelphia, Pa.	....	2.42	13.62
14	H. F. Michell, Philadelphia, Pa.	....	2.73	13.08
**15	Moore & Simon, Philadelphia, Pa.	"M & S's New Royal Danish Ballhead"	2.85	***
16.	W. W. Rawson, Boston, Mass.	"Emperor or Danish Ballhead"	3.44	17.39
17	W. P. Stokes, Philadelphia, Pa.	....	2.46	9.84
18a	J. M. Thorburn, New York, N. Y.	"Tall"	2.53	11.02
*18b	J. M. Thorburn, New York, N. Y.	"Dwarf"	2.44	8.07
19a	Vaughan's Seed Store, New York, N. Y.	....	1.87	9.53
19b	Vaughan's Seed Store, New York, N. Y.	"Dwarf Amager or Short Stem'd Danish Ballh'd"	2.85	13.23
20a	Jas. Vick's Sons, Rochester, N. Y.	Danish No. 6390	2.28	9.14
20b	Jas. Vick's Sons, Rochester, N. Y.	Dwarf Danish No. 7452	2.59	9.19
20c	Jas. Vick's Sons, Rochester, N. Y.	Hollander American Grown ...	3.79	16.94
22	The Livingston Seed Co., Columbus, O.	....	2.40	9.90
23	Chas. H. Lilly & Co., Seattle, Wash.	No. 1725	2.54	10.20
24	Northrup, King & Co. Minneapolis, Minn.	....	3.13	11.11
25	A. G. Tillinghast, La Conner, Wash.	"Puget Sound 1907 Bulk Seed "Strain A" ..	2.47	11.20
*26	W. F. Allen, Salisbury, Md.	....	3.20	***

* 1 year test.

** 2 year test.

*** Too few plants to estimate yield.

A study of this table shows that the average weight of head varied from 1.87 to 3.44 pounds. One strain averaged 3.79 pounds but it was not true to type. One reason for the relatively small head is doubtless due to the fact that this variety is not well adapted to the Hagerstown clay loam soil, the type on which it was grown. However, the variation is of interest as is also the difference in yield of from 6.19 to 20.56 tons, making a difference of 14.37 tons per acre in favor of the better strain.

The next table gives the result of the test of Succession.

Table VI.—General Average of the Test of Succession Cabbage for the Years 1909, 1910 *and* 1911.

Record No.	SOURCE	Average weight of head, pounds	Average corrected yield per acre
1.	Francis Brill, Hempstead, N. Y.	3.65	19.44 T.
2.	H. A. Dreer, Philadelphia, Pa.	3.82	19.16
3.	Jos. Harris, Coldwater, N. Y.	3.57	18.59
4.	S. M. Isbell & Co., Jackson, Mich.	3.60	18.37
5.	The Livingston Seed Co., Columbus, Ohio.	3.54	19.01
6.	W. H. Maule, Philadelphia, Pa.	3.30	15.74
7.	H. F. Michell, Philadelphia, Pa.	3.24	17.67
8.	Northrup, King & Co., Minneapolis, Minn.	3.17	16.70
9.	W. P. Stokes, Philadelphia, Pa.	3.34*	***
10.	Vaughan Seed Co., Chicago, Ill.	3.21	15.56
11.	W. Atlee Burpee, Philadelphia, Pa.	3.40	15.54
12.	W. F. Allen, Salisbury, Md.	3.49	17.89
13.	Wm. Ewing, Montreal, Canada.	4.17	20.68
14.	D. M Ferry & Co., Detroit, Mich.	3.78	19.40
15.	Griffith & Turner, Baltimore, Md.	3.13*	***
16.	Harvey Seed Co., Buffalo, N. Y..........	3.06*	***
17.	Leonard Seed Co., Chicago, Ill.	3.64	18.81
18.	Moore & Simon, Philadelphia, Pa.	3.70**	***
19.	Peter Henderson & Co., New York, N. Y.	3.40	19.14
20.	Jas. Vick's Sons, Rochester, N. Y.	3.95	17.40
22.	J. M. Thorburn, New York, N. Y.	3.47	18.05
23.	Chas. H. Lilly Co., Seattle, Wash.	3.63**	16.35

* 1 year test.

** 2 year test.

*** Too few plants to estimate yield.

It will be seen that there was a rather pronounced difference in the average weight of head, while the yield per acre varied from 15.54 to 20.68 tons, which is somewhat less than was noted with the previous variety.

Table VII gives the record of the test of Premium Flat Dutch.

Table VII.—General Average of the Test of Premium Flat Dutch Cabbage for the Years 1909, 1910 *and* 1911.

Record No.	SOURCE	Average weight of heads. pounds	Average corrected yield per acre*
1.	Francis Brill, Hempstead, N. Y.	3.88	22.53 T.
2.	H. A. Dreer, Philadelphia, Pa.	3.40	18.89
3.	Jos. Harris, Coldwater, N. Y.	3.53	20.60
4.	S. M. Isbell & Co., Jackson, Mich.	3.40	18.79
5.	The Livingston Seed Co., Columbus, Ohio.	3.76	20.87
6.	W. H. Maule, Philadelphia, Pa.	3.83	21.89
7.	H. F. Michell, Philadelphia, Pa.	3.82	22.38
8.	Northrup, King & Co. Minneapolis, Minn.	3.71	***
9.	W. P. Stokes, Philadelphia, Pa.	3.77	20.98
10.	Vaughan Seed Co., Chicago, Ill.	4.47	24.47
11.	W. Atlee Burpee, Philadelphia, Pa.	3.33	16.25
12.	W. F. Allen, Salisbury, Md.	4.04	22.10
13.	Wm. Ewing, Montreal, Canada.	3.86	20.74
14.	D. M Ferry & Co., Detroit, Mich.	3.36	18.22
15.	Griffith & Turner, Baltimore, Md.	4.18	22.08
16.	Harvey Seed Co., Buffalo, N. Y.	3.78	18.11
17.	Leonard Seed Co., Chicago, Ill.	3.91	19.06
18.	Moore & Simon, Philadelphia, Pa.	2.84	***
19.	Peter Henderson & Co., New York, N. Y.	4.00	19.77
20.	Jas. Vick's Sons, Rochester, N. Y.	4.00	16.69
*22.	H. W. Buckbee, Rockford, Ill.	3.83	***
*23.	Chas. H. Lilly Co., Seattle Wash.	4.06	17.86

* 2 year Average.

*** Too few plants to estimate yield.

This table shows that the weight of head varied from 2.84 to 4.18 pounds. At best the larger head is below the size usually desired for this variety, while the smaller one would be considered quite undesirable, which added to the low germination and lack of trueness to type makes it decidedly undesirable as a strain of this variety.

The yield per acre varied from 16.25 to 24.47 tons, a difference of 8.22 tons per acre in favor of the superior strain.

Table VIII. gives the record of the test of Surehead.

Table VIII.—General Average of the Test of Surehead Cabbage for the Years 1909, 1910 *and* 1911.

Record No.	SOURCE	Average weight of heads. pounds	Average corrected yield per acre**
1.	Francis Brill, Hempstead, N. Y.	3.58	18.42 T.
2.	H. A. Dreer, Philadelphia, Pa.	3.41	17.40
3.	Jos. Harris, Coldwater, N. Y.	3.89	15.68
4.	S. M. Isbell & Co., Jackson, Mich.	3.78	17.44
5.	Livingston Seed Co., Columbus, Ohio. ..	3.47	14.80
6.	W. H. Maule, Philadelphia, Pa.	3.63	16.27
7.	H. F. Michell, Philadelphia, Pa.	3.75	18.50
8.	Northrup, King & Co. Minneapolis, Minn.	3.81	16.54
9.	W. P. Stokes, Philadelphia, Pa.	3.50	15.92
10.	Vaughan Seed Co., Chicago, Ill.	3.65	17.72
11.	W. Atlee Burpee, Philadelphia, Pa.	3.89	19.54
12.	W. F. Allen, Salisbury, Md.	3.67	17.04
13.	Wm. Ewing, Montreal, Canada.	3.78	19.70
14.	D. M. Ferry & Co., Detroit Mich.	3.61	17.43
15.	Griffith & Turner, Baltimore, Md.	3.04	14.52
16.	Harvey Seed Co., Buffalo, N. Y.	3.61	15.27*
17.	Leonard Seed Co., Chicago, Ill.	3.39	16.15
18.	Moore & Simon, Philadelphia, Pa.	3.78	19.02
21.	H. W. Buckbee, Rockford, Ill	2.99	14.53
**23.	Chas. H. Lilly Co., Seattle, Wash.	2.87	13.36

* 1 year Average.
** 2 year Average.

From the above table we see that the variation in weight of head and yield was similar to that noted for the preceding variety, but somewhat less pronounced.

The next table gives the results of the test of Volga.

Table IX.— General Average of the Test of Volga Cabbage for the Years 1909, 1910 *and* 1911.

Record No.	SOURCE	Average weight of heads. pounds	Average corrected yield per acre*
1.	Francis Brill, Hempstead, N. Y.	3.36	18.93 T.
2.	H. A. Dreer, Philadelphia, Pa.	3.54	19.04
3.	Jos. Harris, Coldwater, N. Y.	3.47	20.69
4.	S. M. Isbell & Co., Jackson, Mich.	3.19	18.05
5.	Livingston Seed Co., Columbus, Ohio. ..	3.10	20.35
6.	W. H. Maule, Philadelphia, Pa.	3.21	19.03
7.	H. F. Michell, Philadelphia Pa.	3.66	20.46
8.	Northrup, King & Co. Minneapolis, Minn.	4.47	24.58
9.	W. P. Stokes, Philadelphia, Pa.	3.43	18.36
10.	Vaughan Seed Co., Chicago, Ill.	3.72	20.62
20.	Jas. Vick's Sons, Rochester, N. Y.	4.50	25.56

* 2 year Average.

This table shows that there was a variation in weight of head from 3.10 to 4.50 pounds. Likewise, we see that the yield per acre varied from 18.05 to 25.56 tons. Thus there was an average difference in yield of 7.51 tons per acre in favor of the better strain. This variety seems well adapted to the type of soil upon which it was grown.

Conclusion.

From a study of these experiments it will readily be seen that important variations exist within varieties of cabbage. The average variation in yield for the test as a whole is somewhat more than seven tons per acre. Were it possible by the use of fertilizers or improved cultural methods to secure increases in yields to this extent, the results would be considered phenomenal. To do this would entail considerable expense and, furthermore, the results would not be permanent since they would be due to changed environmental conditions. The differences shown by these experiments are not the result of environment, but are due to differences of inherent properties of the seed. The figures as given are the average of the tests· Furthermore, throughout the course of the experiment, all strains have had equal opportunities, and corrections have been made as far as possible for probable differences of soil fertility. Thus the differences noted may be attributed to heredity, a force which is more or less persistent and which acts without expense. It is needless to further emphasize the importance of giving greater attention to this factor in the production of our economic plants. An interesting as well as a significant fact shown by these experiments isthat no one seedsman's strain excelled in every particular variety. A few had some varieties, the strains of which were especially good, and other varieties the strains of which were equally inferior. Other seedsmen had varieties all of which were quite uniformly good, while the varieties of a few seedsmen were generally inferior. This irregularity of results has doubtless come about through lack of proper vigilance on the part of the seedsmen and seed growers. However, it is the natural outcome of a response to the popular demand of the "most for the least money ' Until the purchaser is willing to place quality above price, he can hope for little definite and permanent improvement upon the present condition.

The production of high grade seeds is accompanied with considerable expense. Furthermore, it is frequently the case that well-bred plants produce less seed than those which are poorly bred. Thus, where the grower is paid for quantity rather than quality of product he cannot be expected to put his best efforts into the production of well-bred seed. It is safe to predict that when the importance of well-bred seed becomes known, a demand will be made for it and the price charged will become a matter of secondary importance. Until this time comes, we can suggest no better plan than to purchase from several sources and make a preliminary test. The following year the main crop may be grown from the strain which proved best in the trials. It is true that this method will entail some outlay of money and extra labor, but it is insignificant when compared with the difference between a good and a poor strain, and the satisfaction of securing a satisfactory return for money and labor expended in the growing of the crop. At the time the seed is purchased, it is well to emphasize the fact that high grade seed is wanted regardless of price. By instilling a spirit of cooperation among the farmer, seedsman, and seed grower, much can be done that will be of mutual interest to all concerned.

William [illegible]

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The Pennsylvania State College Agricultural Experiment Station

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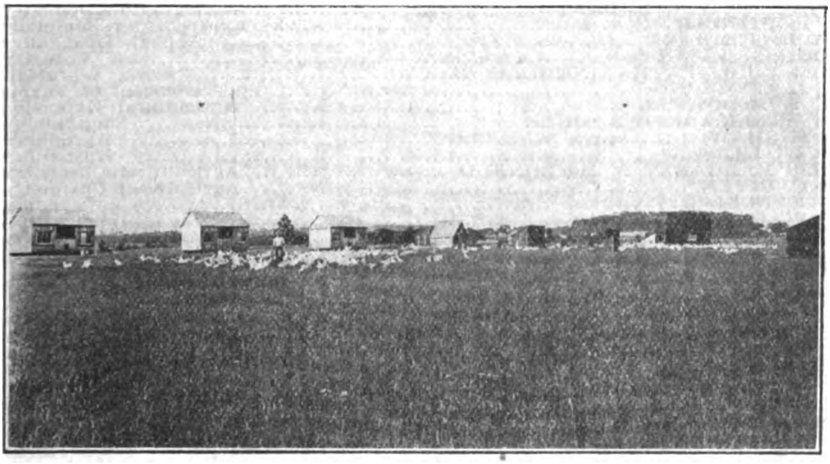
BULLETIN No. 120



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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 120

EXPERIMENTS IN INCUBATION

By HOMER W. JACKSON

Conclusions

Under natural conditions eggs not promptly incubated are subject to daily warming by contact with the hen's body which appears to have an important influence on the life and vigor of the embryo chick;

Warming for 60 minutes gives better results than for 30 or 120;

Eggs held for incubation gave better results when laid flat and turned daily;

No especial difference due to position was noted in eggs held for less than 16 to 18 days;

In both tests poorest results were secured with eggs placed on end and turned daily, as compared with eggs laid flat, or placed on either end and not turned.

Influence of age of eggs on hatchability varied greatly, presumably due to season or conditions of breeding pen;

Washing eggs for hatching materially reduced hatchability;

Eggs placed on end in incubator for first three days of incubation suffered no perceptible injury;

Eggs turned twice daily generally gave better results than those turned once daily.

Most problems connected with artificial incubation are too intricate and many-sided to be disposed of finally, except after several years of investigation. There appears to be no practical way of planning such experiments which will entirely eliminate all points of difference except the one under consideration. While it is not wise, therefore, to attempt to draw final conclusions from a limited number of tests, such tests, if the results are consistent, may be accepted tentatively, and it is with this thought in mind that the results of some investigations in artificial incubation recently undertaken are here given.

All eggs used in these experiments were from the Station flock which consists of Barred Plymouth Rocks, Rhode Island Reds, White Wayndottes and White Leghorns. In most of the experiments, eggs were from Leghorn pens exclusively and as far as possible taken in equal or proportionate numbers from the different pens contributing. Incubators of the same make were used as far as possible. When incubators of different types were used, the eggs were divided as to total and pen numbers or on a proportionate basis.

Treatment of Eggs Held for Hatching.

Results secured with eggs held for a considerable time before being incubated vary quite widely and are dependent on several factors. Experiments indicate that with eggs of good fertility, kept in a reasonably cool room or cellar, there is little difference in hatchability when held for ten days or two weeks, regardless of the condition under which they are kept or the position in which they are placed. After that time, important differences are often noted. Doubtless, the general opinion that eggs for hatching should be incubated as soon as possible after being laid is correct. It is often necessary, however, to hold them for a considerable length of time before setting, and it is a matter of practical importance to know the best possible conditions under which to keep eggs for hatching and the length of time for which they may be held.

The common methods of holding eggs for hatching are more or less at fault as compared with natural conditions. It is observed that eggs held for two or three weeks are usually several hours later in hatching than fresh eggs similarly incubated and that there are more infertile eggs, more dead germs and more feeble chickens than from fresh eggs. It is not probable that there is any such difference between the first and last eggs laid by hens which have stolen their nests and have laid out a full setting and incubated them without being molested. Under such conditions, eggs are often exposed to considerable variation in temperature and necessarily vary in age, the first egg being two or perhaps three weeks older than the last egg laid. There is no reason to believe, however, that under natural conditions, the oldest eggs are any slower in hatching or produce a smaller proportion of chicks than the fresh ones or that the chicks are lacking in vitality. It is a common observation that under favorable conditions such eggs practically all hatch and the chicks are proverbially strong and vigorous. The statement that hens that steal their nests are more vigorous than the average of the flock is sometimes offered in explanation of this fact, though no experiments appear to have been made bearing upon this point. There are however, good reasons for believing that something is due to different treatment received by the eggs prior to incubation.

Fertilization of the egg takes place in the upper part of the oviduct several hours before being laid, and embryonic development has already made some progress when the egg is excluded. There is, therefore, in each fertile egg, when laid, a living embryo, the development of which remains stationary during the period of time for which the egg is held. The exact limit to which we can go in delaying incubation without destroying life depends on several factors, as for example, the vigor of the breeding stock, the temperature at which the eggs are being held, and the position in which they are placed. It appears also to be conditioned upon whether or not the vitality of the embryo has been conserved or maintained by daily warming. The latter point has apparently been overlooked by investigators but the results of long series of experiments indicate that this point is of considerable importance. A consideration of the conduct of the hen under normal conditions will help make this point plain.

The laying hen regularly remains on the nest for a period ranging from one-half hour to two hours when laying, conduct not in any way known to be associated with the act of laying. It is believed that the explanation for this peculiar conduct is to be found in the instinct which prompts the hen to remain on the nest for a sufficient period to warm the embryos of the eggs already laid. If this is the true explanation, it follows that eggs warmed daily for the proper time should remain hatchable for a longer time, should hatch larger percentages and more promptly when incubated, and should produce stronger and more vigorous chicks than eggs held for the same time without warming. The practical difficulties in the way of ascertaining the correctness of this theory have been numerous. Many of the experiments have been more or less imperfect and unsatisfactory and are not reported in this bulletin, the reports here given being entirely from work done in 1910 and 1911. It is fair to say, however, that all previous tests have in varying measure sustained the theory.

The practical value of this observation will depend upon the working out of a convenient means of warming eggs held for hatching, but its importance seems to warrant the effort. Some method will have to be devised to bring the eggs into direct contact with a heated surface, the temperature of which can be maintained at the temperature of the hen's body. Incubators are not available for the purpose, as too much time is required to secure the proper temperature with present methods of heating.

Experiments of 1910.

Beginning April 15, eggs were saved for this work and divided into lots of 24 eggs each at four-day intervals. Eggs were saved until May 5, thus making five groups. They were all from S. C. W. Leghorn hens and were evenly divided as to pens. Eggs in Lot I were laid flat in egg boxes and carefully turned each day, while the eggs in Lot VI were placed under hens for 60 minutes each day after the group was formed. Eggs in Lot VII were treated in the same way, but were placed under hens for 2 hours daily. All eggs were placed in the incubator on May 17, at which time the average age of the eggs in Group I was 30 days; in Group 2, 26; in Group 3, 22; in Group 4, 18; in Group 5, 14 days old, and the eggs in the different groups of Lots 6 and 7 had been warmed in the nest for the corresponding number of days. Table No. I gives results secured in this test:

Table I.

Lot No.	Treatment	Group No.	Age of eggs, days	No. of eggs	No. broken	No. infertile	No. dead germs	No. chicks hatched	% infertile	% dead germs	% chicks from all eggs
I	Laid flat, turned daily	I	Number doubtful, omitted.								
		II	Disappeared								
		III	22	24		1	13	10	4⅙	54.2	41
		IV	18	24		3	10	11	12⅙	41.7	46
		V	14	24	1	0	7	16	0	29.0	69.6
VI	Laid flat, turned, warmed 60 minutes daily	I	30	24		6	11	7	25	46	29
		II	26	24		4	15	5	16⅔	62.5	21
		III	22	24	1	1	11	11	4¼	46	40
		IV	18	24		1	7	16	4	29	66⅔
		V	14	24		4	2	18	16⅔	8⅓	75
VII	Laid flat, turned, warmed 2 hours daily	I	30	24		6	17	1	25	71	4.1
		II	26	24		5	16	3	21	66⅔	12⅓
		III	22	24		1	14	9	4⅙	58⅓	37½
		IV	18	24		1	11	12	4⅙	46	50
		V	14	24		3	8	13	12½	33⅓	54

Totals, Groups III, IV and V

	No. of eggs	No. broken	No. infertile	No. dead germs	No. chicks hatched	% infertile	% dead germs	% chicks from all eggs
Lot I, Not warmed	72	1	4	30	37	5.6	42	52
Lot VI, Warmed 1 hour daily	72	1	6	20	45	8.5	28.2	63.4
Lot VII, Warmed 2 hours daily	72		5	33	34	6.95	45.8	47.2

Eggs in Lot I, Group 1, are omitted from the record because there was some question as to their being properly marked, and the eggs in Group 2 disappeared during the holding period.

It will be seen by a study of this table that eggs warmed one hour were distinctly in the lead as compared with eggs similarly handled in other respects, but not given a daily warming. The figures in the columns under the head of "infertile" and "dead germs" apply to the eggs as tested with an ordinary egg tester. Probably some of the eggs classed as infertile had made some start, but not enough to be detected with the tester. The ordinary egg tester appears to be a practical way of differentiating between the two, as there is really no way of discriminating between eggs that have attained varying degrees of development before being laid and those that have made some slight development after being placed in the incubator. In our tables, therefore, the term "infertile" refers to eggs in which development has not progressed far enough to be recognized with the use of a good egg tester.

Experiments of 1911.

This experiment was duplicated in 1911, with the following variations. In order to have the eggs of the different groups more nearly of the same age, the number of groups was doubled and made up every other day instead of every four days as in the previous test. The number of eggs in each lot was reduced to ten. In the test of 1910, it was apparent that eggs heated two hours had been exposed to too much heat, resulting in too much development prior to incubation. The advantage in warming appears to lie in merely sustaining life, without starting development. It is apparent that a two-hour warming period is too long, resulting in a much larger number of dead germs.

In the test of 1911, Lot VI was warmed for 30 minutes, and Lot VII for 60 minutes. Eggs were saved from May 26 to June 13 and all held until June 22, at which time the eggs of group 1 averaged 28 days of age, and those in Group 10 averaged 10 days of age. The following table gives the results of these tests:

Table II.

Lot No.	Treatment	Group No.	Age of eggs Days	No. of Eggs	No. broken	No. Infertile	No. of dead germs	No. of chicks hatched	% Infertile	% dead germs	% Ch'ks from all eggs
I	Laid flat, turned daily	I	28	10		8	2	0			
		II	26	10		6	4	0			
		III	24	10		7	3	0			
		IV	22	10		1	7	2			
		V	20	10		7	3	0			
		VI	18	10		3	4	3			
		VII	16	10		4	4	2			
		VIII	14	10		2	4	4			
		IX	12	10		0	4	6			
		X	10	10		2	5	3			
VI	Laid flat, turned, warmed 30 minutes daily.	I	28	10		7	3	0			
		II	26	10		4	5	1			
		III	24	10		6	3	1			
		IV	22	10	1	3	5	1			
		V	20	10		5	5	0			
		VI	18	10		0	8	2			
		VII	16	10		2	5	3			
		VIII	14	10		3	3	4			
		IX	12	10		1	5	4			
		X	10	10	1	2	3	4			
VII	Laid flat. turned, warmed 60 minutes daily.	I	28	10	1	3	6	0			
		II	26	10		4	5	1			
		III	24	10		4	3	3			
		IV	22	10		2	6	2			
		V	20	10		3	5	2			
		VI	18	10		3	1	6			
		VII	16	10		0	6	4			
		VIII	14	10		1	5	4			
		IX	12	10	1	1	5	4			
		X	10	10		2	4	4			
	Totals:										
I	Not warmed			100		40	40	20	40	40	20
VI	Warmed 30 minutes daily			100	2	33	45	20	33.7	45.9	20.4
VII	Warmed 60 minutes daily			100	2	23	46	29	23.5	47	29.6

Here again, the warmed eggs lead in per cent. of chickens hatched from all eggs set. Summarizing results of these two tests in comparing eggs warmed one hour with those not warmed, the average number of chicks hatched from 100 eggs, not warmed, from 14 to 30 days old, was 33; from 100 eggs warmed 60 minutes daily, 43 chicks were hatched, a gain of 10% on all eggs used.

It was noticed further in handling the eggs in the incubators in both years, that the embryos of the warmed eggs, after being placed in the incubator, presented a distinctly different appearance from those of eggs not warmed, being more clear cut, larger in size at the same period of incubation, more active and giving every appearance of being stronger and more vigorous. The construction of incubators makes it almost impossible to accurately observe the hatching, but it was noticed that in each instance the first eggs to hatch were the warmed eggs, and the general impression was gained that the chicks from the oldest warmed eggs hatched much more promptly after pipping than eggs of the same age not warmed. The results secured in 1911 indicate that a 30-minute warming is not sufficient for the purpose. It was not practicable to follow the chicks beyond the first few days of brooding, during which time there was no noticeable difference in the vigor of the chicks hatched.

Considering both tests, it seems apparent that there is no particular gain to be secured from warming eggs that are to be held for a period of not more than 10 or 12 days, although this requires further investigation. Apparently the vitality of the embryo suffers when held for a longer period without warming. The average temperature of the room in which eggs are held for hatching purposes has a considerable bearing upon this point, and it has not been practicable for us to make any investigations along this line. The average temperature of the egg room in 1910 was 51.6 and 58.1 in the evening; maximum temperature, 72; minimum temperature, 43. The temperature for 1911 was no doubt higher, being much later in the season, but exact data on this point are not available.

Position of Eggs Held for Hatching.

While carrying on this experiment in 1910 and 1911, it seemed desirable to incorporate with it a test of the effect of placing eggs in different positions while holding them for hatching, a point upon which there is at present a wide difference of opinion and practice, and a lack of exact data. Additional lots, therefore, were formed as follows: Lot 1, eggs laid flat and turned daily; Lot 2, laid flat and not turned; Lot 3, placed with the big end up and not turned; Lot 4, placed with the small end up and not turned; Lot 5, placed on end and turned daily. The same number of groups in each lot was provided as in the preceding experiments, and the following tables give the results of this test in each year. For lack of space, detailed tables of this experiment are omitted and totals only are shown.

Table III, Experiment of 1910.

Totals	No. of eggs	No. broken	No. infertile	No. of dead germs	No. of chicks hatched	% infertile	% dead germs	% chicks from all eggs
Laid flat and turned	72	1	4	30	37	5.6	42.2	52.1
Laid flat, not turned	96		29	20	47	30.0	21.0	49.0
On end, turned	120	1	29	44	46	24.3	37.0	38.7
Large end up, not turned	120	1	30	40	49	25.2	33.6	41.2
Small end up, not turned	120	1	32	30	57	26.9	25.2	47.9

Table IV. Experiment of 1911.

Totals	No. of eggs	No. broken	No. infertile	No. of dead germs	No. of chicks hatched	% infertile	% dead germs	% chicks from all eggs
Laid flat and turned	100		40	40	20	40	40	20
Laid flat, not turned	100	1	23	57	19	23.3	57.5	19.2
On end, turned	100	1	34	48	17	34.3	48.5	17.2
Large end up, not turned	100	1	30	46	23	30.2	46.5	23.2
Small end up, not turned	100	1	32	52	15	32.3	52.5	15.2
Totals both tests:								
Laid flat, turned	172	1	44	70	57	25.7	40.9	33.3
Laid flat, not turned	196	1	52	77	66	26.6	39.5	33.8
On end, turned	220	2	63	92	63	28.9	42.2	28.9
Large end up, not turned	220	2	60	86	72	27.5	39.4	33.0
Small end up, not turned	220	2	64	82	72	29.3	37.6	33.0

The results are not entirely consistent in these two tests, but it is apparent from a study of the detailed tables that after the first two weeks there is a distinct disadvantage in leaving eggs flat without turning, and that apparently eggs laid flat and turned give better results than those kept in any other position. In view of the fact that such is the natural position for eggs while being held for hatching, there would seem to be an added reason for following that method.

Hatchability of Eggs Held for Different Periods.

Rearranging the data of the preceding experiments and combining eggs of the same age of all lots together, the following table gives the results secured with eggs incubated at different ages.

Table V.

	Age of eggs, days	No. of eggs	No. broken	No. infertile	No. dead germs	No chicks hatched	% infertile	% dead germs	% chicks from all eggs
Test of 1910	30	96	0	50	23	23	52.1	24	24
	26	96	1	22	31	42	23.2	32.6	44.2
	22	120	1	17	44	58	14.2	37.0	48.7
	18	120	0	15	36	69	12.5	30.0	57.5
	14	96	2	11	30	53	11.2	32.0	56.4
Test of 1911	28	50	2	32	16	0	66.6	33.3	0
	26	50	0	29	21	0	58.0	42.0	0
	24	50	0	26	23	1	52.0	46.0	6
	22	50	0	15	32	3	30.0	64.0	6
	20	50	1	20	29	0	40.8	59.2	0
	18	50	0	10	26	14	20.0	52.0	28
	16	50	0	10	20	20	20.0	40.0	40
	14	50	0	8	24	18	16.0	48.0	36
	12	50	0	5	26	19	10.0	52.0	38
	10	50	0	5	27	18	10.0	54.0	36

Results, while not particularly consistent, show that there is comparatively little loss in the hatchability of eggs up to the first two weeks, and where fertility is good, up to three weeks, and a rapid drop after that time, facts agreeing quite generally with common experience.

Miscellaneous Experiments.

During 1911, a number of miscellaneous experiments were made and are here reported, although in some instances the tests have not been duplicated as often as is desirable. It should be explained that the fertility this season was generally quite low and irregular, and this no doubt has some bearing on the practical value of the results secured.

The Effect of Washing Hatching Eggs.

It is frequently desirable to set eggs that have been badly soiled, especially from valuable stock, and it is interesting to know whether such washing seriously affects the hatchability of the eggs. In the tests here reported, eggs were equally divided as to pens, age, etc. One-half was selected as soiled eggs and one-half set without any treatment. Where there were not enough soiled eggs to make up the number, clean eggs were used, but they were carefully washed also.

It is apparent from Table VI given below that there is a distinct disadvantage arising from washing eggs, and it is recommended that, unless eggs are badly soiled, they be set without washing. It is worth noting in this connection, however, that if badly soiled eggs are to be used, it is better to wash them than to place them in the machine without washing, and nothing in this experiment should be construed as advising the continuing of eggs in incubator or nest which may have been accidentally soiled during incubation. It is particularly important that eggs that have been soiled in the nest should be washed, as the loss resulting from washing is not as great as would be the loss which would result from leaving the eggs covered with filth.

Table VI.

Incubator	Treatment	No. of eggs	No. broken	No. infertile	No. dead germs	No. dead after pipping	No. of chicks	% chicks from all eggs
1st Test								
P. S. No. 9.	Washed	50	0	7	21	2	20	40
P. S. No. 9.	Unwashed	50	0	5	13	2	30	60
2nd Test								
Model 14	Washed	60	0	13	26	1	20	40
Model 14	Unwashed	60	1	10	18	0	31	63.3
3rd Test								
P. S. No. 8.	Washed	50	0	4	18	1	27	54
P. S. No. 8.	Unwashed	50	0	8	18		24	48
4th Test								
P. S. No. 15	Washed	60	0	13	26	0	21	35
P. S. No. 15	Unwashed	60	0	6	20	4	30	50
Totals	Washed	220	0	37	91	4	88	40
	Unwashed	220	1	29	69	6	115	52.5

Effect of Crowding Eggs in the Incubator.

Many poultrymen, in the effort to set the maximum number of eggs in their machines, follow the practice of standing them practically on end during the first few days of incubation, a fact which considerably increases the number which may be placed in the machine. At the end of the third day the eggs are tested, and a sufficient number of infertile eggs are usually removed to make it possible to place the remainder in the proper position for the rest of the hatch. It has been thought by some that this method of handling might result in an improper placing of the embryo, which might affect either the number of dead germs or the number of chickens unable to escape from the shell at hatching time. The following table gives the results of three tests, from which the obvious conclusions may be drawn that there is no serious disadvantage resulting from this crowding, provided the eggs are tested out at the end of the third day.

This method is only possible where white-shelled eggs are used, as development has not gone far enough to be detected in brown-shelled eggs, with ordinary testers, at this time. While the practice is not recommended, there is nothing in the experiments that have been made to indicate that there is any serious objection to following it.

Table VII.

Incubator Treatment		No. of eggs	No. broken	No. infertile	No. of dead germs	No. dead after pipping	No. of chicks	% chicks from all eggs
1st Test								
Cyphers No. 13	Crowded	145	3	6	48	1	87	60
Cyphers No. 13	Regular No.	120	1	8	37	3	71	59.6
2nd Test								
Cyphers No. 12	Crowded	147	1	12	54	3	77	52.7
Cyphers No. 12	Regular No.	123	2	14	44	1	62	51.2
Totals	Crowded	292	4	18	102	4	164	57
	Regular No.	243	3	22	81	4	133	55.4

Frequency of Turning Eggs in Incubator.

While the general practice is to turn eggs twice a day after the second day, there is sufficient difference of opinion in regard to the advisability of this semi-daily turning to make it worth while to investigate the matter a little more carefully, and the following table gives the results of five tests which were made, comparing semi-daily and daily turning.

Table VIII.

Incubator Treatment	No. of eggs	No. broken	No. infertile	No of dead germs	No. dead after pipping	No. of chicks	% chicks from all eggs
1st Test							
P. S. No. 3 Turned once daily	154	1	11	57	3	82	53.6
P. S. No. 3 Turned twice daily	154	0	10	58	2	84	54.5
2nd Test							
Cyphers No. 12 Turned once daily	122	0	5	39	2	76	62.3
Cyphers No. 12 Turned twice daily	122	1	4	33	0	84	69.4
3rd Test							
P. S. No. 15 Turned once daily	120	0	13	41	2	64	63.3
P. S. No. 15 Turned twice daily	120	0	6	21	4	69	57.5
4th Test							
P. S. No. 3 Turned once daily	152	0	8	27	4	113	74.4
P. S. No. 3 Turned twice daily	152	0	13	27	1	111	72.0
5th Test							
P. S. No. 14 Turned once daily	126	0	16	38	4	68	54.0
P. S. No. 14 Turned twice daily	127	0	16	31	3	77	60.6
Totals							
Turned once daily	674	1	53	202	15	403	59.8
Turned twice daily	675	1	59	170	10	445	66.0

This table shows conclusively that turning twice daily is likely to give better results than a single turning, although the fourth test gave slightly opposite results. No effort was made to investigate the desirability of turning eggs oftener than twice.

CRUDE FIBER IN THE RATION OF LAYING HENS.

By W. A. COCHEL and HOMER W. JACKSON

Conclusions.

Rations carrying 3½ per cent. of total weight in crude fiber seem to give better results than those with lower or higher percentages.

Fowls can keep in fairly good condition on a ration carrying 5 per cent. fiber but will show decreased egg yield;

Fowls fed freely on rations carrying over 5 per cent. fiber suffer from serious intestinal disorders;

Fowls on rations carrying 6½ per cent. fiber and over will probably keep in fair condition if consumption is reduced to maintenance requirements;

Fowls do not seem to make any appreciable use of coarse floor litter to supply deficiency in fiber content of ration;

Confining fowls to house pens or permitting them to run in large yards seems to have no bearing on relative performance on different percentages of fiber;

Amount of green feed consumed is governed to some extent by proportion of crude fiber in ration;

Fowls keep in better health and lay better with bran as a source of fiber than alfalfa meal;

Fowls will not eat alfalfa meal unless compelled to do so by mixing with other more palatable feed stuffs;

Fowls apparently are fond of alfalfa hay, but the proportion actually consumed is small;

Under the conditions of these experiments, fowls with unlimited alfalfa or bran will make up rations carrying approximately 3.5% crude fiber;

It is conceded that fowls are able to digest very little crude fiber, and presumably the chief beneficial result that may be anticipated from its presence in the ration is the dilution of the contents of the crop, gizzard, and intestines which may render the ration as a whole more digestible. Whether this be true or not, it is apparent that there must be comparatively narrow limits within which entirely indigestible feed stuffs may be used to advantage. For the purpose of ascertaining what these limitations may be, a series of experiments have been planned, the first of which was undertaken in the summer of 1910 and continued in 1911. Incidentally, a test of alfalfa, bran and cob meal as a source of fiber was undertaken. Our experiments along this line are by no means concluded, but sufficient data have been accumulated to make their publication desirable at this time.

Experiments of 1910.

In the first experiment, it was planned to deprive the fowls of every possible source of fiber except that given in the ration. To this end, the nests were made of burlap stuffed with excelsior; the cement floors of the houses were covered with sand, and the fowls were kept constantly confined to these pens during the two periods of the experiment. As this work was carried on during the summer, the pens were quite warm at times and the fowls suffered more or less from heat. No doubt this affected the general health and performance of the pens, but there is no reason to think that one pen was at greater disadvantage than another. Six pens were used, each consisting of 16 S. C. W. Leghorn hens one year old, and the rations were composed of corn, alfalfa meal and meat scrap in varying proportions. Lettuce was used for green feed, being selected as lowest in fiber of all sources of available green feed. It was impossible to keep an exact record of the total weight of green feed consumed by each pen. Such weights as we were able to take indicated an irregular and more or less inconsistent consumption in all pens, but in general, the amount consumed in the low fiber pens was decidedly in excess of that consumed by the high fiber pens.

All the rations for the pens were estimated on the basis of a nutritive ratio of 1.5 crude nutrients, and were made up on the following formulae:

Pen No. 1.—100 lbs. cracked corn and corn meal, 16 lbs. meat scrap, 1 lb. alfalfa. Crude fiber 2%.

Pen No. 2.—100 lbs. corn and corn meal, 13 lbs. meat scrap, 13 lbs. alfalfa meal. Crude fiber 3.5%.

Pen No. 3.—100 lbs. cracked corn, 10 lbs. meat scrap, 30 lbs. alfalfa meal. Crude fiber 5%.

Pen No. 4.—100 lbs. corn, 7 lbs. meat scrap, 45 lbs. alfalfa. Crude fiber 6½%.

Pen No. 5.—100 lbs. corn, 2 lbs. scrap, 75 lbs. alfalfa meal. Crude fiber 8%.

Pen No. 6.—100 lbs. corn meal, 16 lbs. meat scrap, alfalfa meal *ad. lib.*

All pens showed loose bowels at the start, due apparently to an abnormal consumption of sand. Wooden feed troughs were used, and to prevent waste of feed stuffs, these were placed in large tin troughs so constructed that when the fowls threw feed out of the trough it dropped down between the wooden trough and the outer tin trough, and all waste was prevented. During the first week, whole corn was used, but the pens receiving large proportions of alfalfa consumed so little of it that it was not possible to maintain the prearranged proportion of fiber without putting fowls on very light rations. At the end of the first week, cracked corn was substituted and some corn meal added to the alfalfa and meat scrap in order to make the whole ration more palatable and secure the proper proportionate consumption of alfalfa. The mixture was moistened with enough water to make a crumbly mash and fed twice daily. The mash was left before the hens for half an hour or an hour, when the surplus was removed and mixed with the next feeding. Hens that were entirely off feed were removed from the pen, although practically all such died subsequently. Table I gives the results of the experiment for the first period of 21 days.

Table I (First Period)

Pen No.	Days	No. of hens	% fiber	1st average wt.	Final av. wt.	No. out	Lbs. feed	Eggs produced 1st week	2nd week	3rd week	Total No. of eggs
1	21	16	2	2.76	2.54	1	46.14	25	14	20	59
2	21	16	3½	2.82	2.93	0	52.60	21	22	22	65
3	21	16	5	2.77	2.64	2	47.50	38	14	11	63
4	21	16	6½	2.80	2.72	4	38.92	22	4	4	30
5	21	16	8	2.81	2.63	3	27.20	14	1	2	17
6	21	16	2	2.73	2.40	1	39.90	18	22	14	54

Table II. (Second Period)

1	21	15	2	2.54	2.72	0	38.82	13	31	17	61
2	21	16	3½	2.93	3.18	2	52.00	27	42	32	101
3	21	14	5	2.64	2.83	2	42.30	23	24	17	64
4	21	12	6½	2.72	2.80	1	43.12	17	21	17	55
5	21	13	6.8	2.63	2.92	0	48.00	2	11	21	34
6	21	15		2.40	2.66	1	42.30	8	26	21	55

It will be seen by this table that best results as to egg yield and health of fowls were secured with ration No. 3, carrying 3½% crude fiber. The appetites of fowls in Pen No. 1 with 2% fiber were apparently cloyed by the too concentrated ration. While the results in Pen No. 6 were fairly good, a similar condition existed there, as the fowls in this pen absolutely refused to eat alfalfa meal either wet or dry, and the ration, therefore, was practically the same as that in Pen No. 1. Pen No. 3 with 5% fiber kept in a fairly good condition on a rapidly decreasing egg yield. Pens No. 4 and No. 5 on 6½ and

8 per cent. fiber were in distress most of the time and suffered greatly from inflammation of the bowels and were only able to stand the ration by limiting their consumption of it as compared with the consumption in Pens 2 and 3.

Second Period:—At the beginning of the fourth week, without making any change in the pens, bran was substituted for alfalfa as a source of fiber, retaining the original nutritive ratio of 1.5 and the same percentage of fiber. At the time of making the change, all pens had begun to improve somewhat in condition, possibly having become better accustomed to their ration. The pens on the extreme rations were apparently trying to meet the conditions enforced by the experiment. The change in condition, therefore, which accompanied the change in ration was not due entirely to the substitution of bran for alfalfa, but without doubt the larger part of the difference can be so attributed.

Table III gives the results for three weeks on this ration. A study of this table will show that while all pens made a decided improvement in condition in the second period they retained their relative rank as compared with the first period. In Pen No. 5, in which cob meal had been substituted for alfalfa, the fowls made a noticeable improvement in condition, though it should be noted that the percentage of crude fiber was reduced to 6½% as in No. 4.

Experiments of 1911.

The experiments this year began March 19, and are a duplication of the work done in 1910, with some changes in detail. Seven pens were used in this experiment with ten S. C. W. Leghorn pullets in each pen. During the first period, they were confined in colony houses, such as shown in Fig. II. These houses were littered with straw and planer shavings and fowls were confined continuously to them. The results of the experiment in 1910 indicate so clearly the disadvantage of using high fiber rations that it was decided to omit the rations carrying 6½% and 8% of fiber and instead to use only rations carrying 2%, 3½% and 5% fiber and providing duplicate pens for each ration. In this experiment, therefore, Pens No. 1 and No. 2 received a 2% fiber ration; Pens No. 3 and No. 4 received the 3½% fiber ration; Pens No. 5 and No. 6 the 5% ration; and No. 7 was permitted to determine for itself the amount of fiber to be consumed. The season of the year was more favorable for experimenting with hens in confinement, and partly due to this cause and partly to the littering of the floor with straw and shavings the fowls remained in better condition. The rations were made upon the same formulae as in 1910. Cabbage and dried beet pulp were used for green feed, as lettuce was not available. Table III gives a record of the pens for the first four weeks:

Table III (First Period)

Pen No.	Weeks	No. of hens	% fiber	1st average wt.	Final avg. wt.	No. out	Lbs. feed	Eggs produced 1st week	2nd week	3rd week	4th week	Total No. of eggs
1	4	10	2	2.78	2.75	0	43.30	27	9	11	19	66
2	4	10	2	2.82	2.87	0	45.00	23	9	24	15	71
3	4	10	3½	2.70	2.70	0	42.70	24	10	8	21	63
4	4	10	3½	2.90	2.84	0	48.63	27	21	26	21	95
5	4	10	5	2.65	2.67	0	38.87	22	5	3	13	43
6	4	10	5	2.80	2.86	0	44.40	25	5	8	22	60
7	4	10	3.4	2.78	2.93	0	43.70	22	29	37	36	124

Table IV (Second Period)

1	12	10	2	2.75	2.66	1	117.60					283
2	12	10	2	2.87	2.85	0	129.75					355
3	12	10	3½	2.70	2.60	0	122.60					315
4	12	10	3½	2.84	2.83	0	133.00					365
5	12	10	5	2.67	2.55	1	109.28					210
6	12	10	5	2.86	2.68	0	111.90					313
7	12	10	3.2	2.93	2.83	0	127.00					362

Table V (Third Period)

1	8	10	2	2.90	2.83	0	78.50					129
2	8	10	2	2.85	3.14	1	77.81					102
3	8	10	3½	2.60	2.93	0	91.00					165
4	8	10	3½	2.83	2.88	0	87.35					133
5	8	10	5	2.55	2.67	0	84.63					68
6	8	10	5	2.68	2.68	0	84.25					114
7	8	10	3.3	2.97	3.20	0	83.20					147

Comparisons, either with duplicate pens or with results secured in 1910, show fairly consistent results, and point to a 3½% fiber content as the practical proportion in which fiber should be combined with the ration. Under the conditions of these experiments, the use of litter on the floor in no way affected the relative performance of the different lots, indicating that a deficiency in fiber in the ration will not normally be remedied by consumption of coarse and unpalatable materials. At the end of the four weeks there was some falling off in condition in most pens, apparently as a result of confinement, but little of which can be directly attributed to the ration fed. No. 7, however, was in better condition than any of the rest. In this pen, alfalfa was supplied in the form of alfalfa hay. Some little trouble was experienced in feeding this in such a manner as to prevent waste, and weights given for alfalfa in this pen are approximate only. It was noticed that while this pen seemed to eat the alfalfa greedily, piling into the tub in which it was fed as the supply was renewed and appearing to be very eager for it, the actual consumption was much lower than was expected.

At the end of four weeks, the different pens were transferred to scratching shed pens with fairly large yards to which the fowls were given access and where they were continued on the ration for a further period of 12 weeks. After the transfer, all the fowls improved in condition, due to the opportunity for more exercise and possibly to extra green feed secured in the yards, but the health and performance of the hens on 3½% fiber continued to be better than of those either higher or lower. There seemed to be no advantage in continuing this test longer than 12 weeks as apparently the pens might all have been continued indefinitely with about the same relative results as had been obtained up to this time. Table IV gives results secured during this period.

On July 10, the rations were changed, substituting bran for alfalfa as a source of fiber, as in the original experiment in 1910. The pens were continued as in the second period, except that missing birds in Pens No. 1 and No. 5 and one very sick one in Pen No. 7 were replaced from the general flock, so that all pens started anew at this time with the original number of ten. All fowls seemed to be in fairly good health, but with a noticeable difference in condition favoring Pens No. 3 and No. 4, while Pens No. 5 and 6 may be classed as second best. Pen No. 7, which was one of the best pens during most of the experiment, had lost a little in condition by the end of the second period. The rations were made up on the same formulae as given for the bran ration in 1910. The pens were continued on these rations for eight weeks, and Table V gives results.

After the change in rations, all pens made prompt improvement in appearance, weight and production just as they did the year before and it is impossible to resist the conclusion that, considering the health of fowls, bran as a source of fiber is better than alfalfa.

Weight of Eggs as Affected by Rations.

Eggs from the different pens were weighed and some examination was made of their appearance and contents, but differences noted were slight and not particularly consistent.

Table I.

Pen No.	Treatment	Length of period	Av. No. hens	Breed	Av. wt. Dec. 14, 1910	Av. wt. Sept. 18, 1911	Av. No. eggs per hen	Feed cost of eggs per doz.	Av. lbs. feed consumed per hen per month
12	Ration of wheat, corn & dry mash	39	43.9	S. C. W. Leghorns	2.78	2.53	78	13	5.9
14	Ration of corn, bran and scrap	39	43.4	S. C. W. Leghorns	2.83	2.92	81.7	11.1	5.8
1	Wheat, corn and dry mash	24	8⅔	B. P. Rocks	Mar. 30 5.2	4.57	58	12.5	6.9
2	Corn, bran and scrap	24	9	B. P. Rocks	5.4	4.72	45	12.8	6.15
5	Wheat, corn and dry mash	24	16	R. I. Reds	4.8	4.4	58.7	11.2	5.97
6	Corn, bran and scrap	24	14½	R. I. Reds	4.71	4.87	62.4	10.6	6.7

A COMPARISON OF SIMPLE RATIONS WITH VARIETY IN FEEDING LAYING HENS

By W. A. Cochel and Homer W. Jackson.

CONCLUSIONS

Without attempting a too general application of these experiments, the following conclusions are suggested tentatively:

Pullets of Barred Rock, Rhode Island Red and Leghorn breeding will keep in good health on rations carrying very large proportions of corn if bran is also liberally supplied;

A ration of corn, bran and meat scrap does not result in heavy production when long continued;

Eggs from hens on such a ration are larger than where wheat is the principal grain fed;

Hatchability of eggs and vigor are increased by a liberal use of corn in the rations;

The results of this experiment with pullets should not lead to the adoption of extremely heavy corn feeding if other grains are available;

Further experiments will be necessary to prove that a corn, bran and meat ration is a safe ration for general use, particularly, with fowls in confinement;

These experiments were made with pullets; care must be exercised in applying results to flocks of older hens;

Eggs can be produced more cheaply on a corn, bran and meat ration than on more varied rations, if the same proportionate egg yield is secured;

In the determination of the nature of the feed stuffs which should be used in supplying variety in the ration of the laying hen and the extent to which we should go in meeting this assumed need, we have to consider the practical side of the question as well as personal convenience. It is assumed that fowls will do best when given the things they want and practically all they want. It is apparent, however, that there is a point at which the choice of variety must be limited or the increased cost of feeding will wipe out the value of the increased production. Just where the lines cross is not entirely clear. It would seem that the poultryman who insists upon feeding a single grain in very large proportion simply because it is cheap or convenient, is as far wrong as he who insists on providing certain grains regardless of cost. As a step in the direction of solving the problem of ration values and their influence on production, some experiments have been conducted here comparing a ration of corn, bran and meat scrap with one consisting of corn, wheat and a mixed mash consisting of equal parts of bran, middlings, corn meal, ground oats, shredded wheat waste, oil meal and meat scrap. The conditions of the experiment were somewhat extreme, as the pens used were confined to comparatively small yards during the entire time of the experiment. It was felt, however, that if fowls so yarded would give good returns on the simpler ration, there could be no question about the results with fowls on range.

The first test was made with two pens of 50 S. C. W. Leghorn pullets each, and ran from Dec. 14, 1910 to Sept 13, 1911. Equal floor space in the same house was given to both pens and fair-sized yards on the north side of the house were utilized during open weather. Both pens were fed grain night and morning. Pen No. 12 received wheat in the morning and corn in the evening, but wheat was substituted in the evening feed when the hens seemed to be indifferent to corn. The mash mixture already mentioned was kept before the fowls all the time, in a large box on the floor. Pen No. 14 received corn morning and evening and had bran and meat scrap mixed in the proportion of four parts bran to one of scrap. Table I gives a summary of the data secured in this test.

It is generally believed that the breed of fowls bears an important relation to success in feed tests of this sort, and beginning with March 30 two additional tests were started, using two pens of ten Barred Plymouth Rock pullets each, in one test and two pens of Rhode Island Red pullets in the other, 16 pullets being in Pen No. 5 and 17 in Pen No. 6. This experiment ran to Sept. 13. A summary of the data secured in these two tests is also given in Table I. In the case of the Leghorn and Rhode Island Red pens, the experiment indicates that the variety ration had no advantage whatever over the simpler feeding, as slightly better results were secured in both cases with the simple ration. Whether or not the fact that the Barred Plymouth Rocks gave much poorer results on the simpler ration can be attributed to the breed or to chance, can only be ascertained by a duplication of the work.

Weight of Eggs as Affected by Feed.

The following table gives the weight of all eggs laid by these pens from May 25 to June 8, computed to 100 eggs from each pen.

Table II.

Pen No.	Treatment	Wt. of 100 Eggs
1	Variety Ration	185.975 oz.
2	Simple "	191.07 "
5	Variety "	185.99 "
6	Simple "	189.13 "
12	Variety "	182.27 "
14	Simple "	179.20 "

It will be seen that in the Plymouth Rock and R. I. Red tests the eggs from the pen fed on the simple ration were larger than the others. In the case of the Leghorns, the situation seems to be reversed. It is believed, however, that if the weights from the Leghorn pen had been taken during the entire season, a much different result would have been shown, as the larger size of the eggs from the corn-fed pen was a matter of general observation and comment during most of the incubating season.

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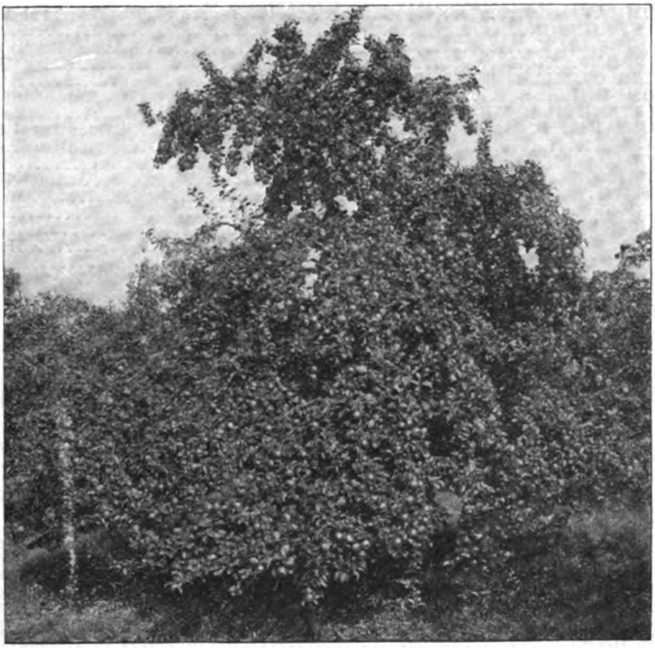
The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 121



A TYPICAL FERTILIZED TREE, EXPERIMENT 220

THE FERTILIZATION OF APPLE ORCHARDS

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
APRIL, 1913

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 121

THE FERTILIZATION OF APPLE ORCHARDS

By JOHN P. STEWART

SUMMARY

1. The experiments of this Station have shown that the fertility needs of an orchard may be the most important check on its production. Variations in fertilization alone have resulted in average differences ranging from 50 to 460 bushels per acre annually for the past four or five years, depending on the experiment. These results were accompanied by similar differences in the growth and general vigor of the trees.

2. The present bulletin indicates briefly the methods and conditions under which some of these results have been obtained, and it outlines a simple method of determining whether or not similar results can be secured in any particular orchard. It also considers the total plant-food requirements of a productive orchard, and indicates the more important effects that follow the application of the different fertilizer elements.

3. The total plant-food draft of a mature and active orchard is greater than that of a 25-bushel crop of wheat in every important constituent except phosphorus. It is practically inevitable, therefore, that sooner or later the output will be reduced or off seasons will be developed in any productive orchard because of a lack of sufficient plant food.

4. The mineral requirements of wood are comparatively low. This largely accounts for the fact that young trees usually do not make a profitable response to fertilizer applications, although they frequently respond well to manure or to other methods of conserving moisture.

5. The relative amounts of the various food elements required by the other parts of the apple plant are also of interest, but as a rule they are not especially reliable as bases for making fertilizer applications. The latter are best determined experimentally, as there seems to be very little relation between the response of the trees and their total chemical requirements.

6. Applications of nitrogen and phosphates and also of manure have been very beneficial in the Johnston and Brown orchards. In those orchards, potash has been of little or no service. These results are reversed at the present time in the Tyson orchard, so far as yields are concerned.

7. The time required for results to appear has been surprisingly short in all cases where fertilization has proved to be really needed. In such cases, both the value of fertilization and the kinds needed were clearly evident by the middle of the second season, and no material changes have occurred since.

8. Neither acid phosphate nor "floats," when applied alone, have resulted in any important benefit. We are therefore "completing" the fertilization of their plats by the addition of nitrogen and potash, in order to test further their relative values as carriers of phosphorus for trees. Basic slag was introduced into this comparison in 1912.

9. Lime also has failed in most cases, though it may have some value in aiding growth. In addition, it may have some indirect value in facilitating the growth of leguminous intercrops, and also in correcting a possible toxic action possessed by the basic radicals of a number of salts, some of which are present in commercial nutrients. (See Annual Reports for 1910-11, pp. 454-55 and 461-65.)

10. At present the high-grade sulphate in our experiments is showing no superiority over the muriate as a carrier of potash, but the reverse is usually true. The lower cost and easier handling of the latter therefore give it the preference. It is possible that the

low-grade sulphate, or the 24 per cent. "double-manure salt," as it is often called commercially, may be superior on account of its magnesia content, but this has not yet been fully demonstrated.

11. The influence of proper fertilization is not transient. The gains from it have been greater in the sixth and last year of some of our experiments than at any time before. In one case, these gains have exceeded 1,100 bushels per acre. Where the crops of the full years are not too high, the yields usually have been greatly steadied by proper fertilization.

12. In all our experiments, the action of manure has proved to be practically identical with that of a commercial fertilizer rich in nitrogen and phosphorus. Their successes and failures have coincided with but two exceptions, and in those cases moisture rather than plant food was apparently the controlling factor. The commercial nitrates and blood have acted more quickly than the manure, and the potash in the latter has apparently been less effective than that in the commercial forms.

13. In general, the influences that have materially increased the yields have also increased the growth. This is true generally, unless either occurs to an abnormal extent. The phosphates seem to be a partial exception to this rule, and mild injuries also may stimulate yield at the expense of growth.

14. Manure and potash are the only fertilizing materials that have shown a consistent benefit on the average size of the fruit. This is doubtless associated with their favorable relations toward available moisture, which is the chief determiner of fruit size. Above a rather indefinite point, however, the size of the crop on the tree becomes the dominant influence on fruit size. Proper thinning and moisture conservation, therefore, are the most important means of improving the average size of fruit.

15. The red colors in apples can not be increased materially by any kind of fertilizer applications, though potash and possibly phosphates may be of some slight assistance. These colors are directly dependent upon sunlight and maturity, with the latter occurring preferably on the tree. Late picking, open pruning, light soils, sod culture and mildly injurious sprays, therefore, tend to increase the reds in fruits, while opposite conditions decrease them.

16. The retarding influence of nitrogenous fertilizers or manure on color makes it advisable to use them less freely on some

of the red varieties, especially those in which the color comes on rather tardily, such as the York Imperial. On the lighter soils, or in localities with the longer growing seasons, this precaution is less important.

17. In the sixth section above, it has been noted that the fertilizing elements found effective in certain experiments were not so in others. In one of our experiments, no form of fertilization has yet shown a profitable response, and in two others such responses have come only from manure and mulches. It is evident therefore that the actual fertilization of a given orchard is still largely a local problem.

18. It is possible, however, to indicate the more prominent characteristics of orchards that are in need of fertilization, and to formulate a general fertilizer, based on present experimental results, that may be used in such orchards until more definite local data can be secured. This has been done on pages 23 to 27, with an additional note on methods of application.

19. Present evidence indicates that the nitrates, or other specially soluble plant foods, are best applied somewhat after the fruit has set. In addition to greater effectiveness, this delay enables the rate of application to be varied somewhat in accord with the amount of fruit set, making the applications heavier when the crop is heavy and vice versa. In the long run, this plan should steady the yields and get maximum benefits from the fertilization applied.

20. The general fertilizer that we are now recommending is a combination carrying about 30 pounds of actual nitrogen, 50 pounds of actual phosphoric acid (P_2O_5), and 25 to 50 pounds of actual potash (K_2O). These are the amounts per acre for bearing trees. Only where potash is known to be needed, should the larger amount be used. Suitable carriers and formulas for obtaining these materials are given in Table VI and its context.

21. This general fertilizer can be modified and directly adapted to the actual needs of any orchard, by following the local testing plan indicated in Table VII. Such a test requires some work, but for those whose livelihood depends to a considerable extent upon their fruit, the time thus spent should be most profitable.

INTRODUCTION

The experiments started by the writer in 1907-8, as a part of the work of the Station, have shown that the plant food needs of an orchard may be the most important check on its production. By variations in fertilization alone, we have obtained average differences in yield ranging from 50 to 460 bushels per acre annually for the past four or five years. This means that, with a valuation of only 50 cents per bushel for the extra fruit, we have had average profits from fertilization running up to more than $200 per acre annually. The accompanying differences in growth and general vigor of the trees have been almost as marked.

The present bulletin indicates some of the conditions and methods by which these results were obtained, and it outlines a simple plan for determining whether or not similar responses can be secured in any particular orchard. A complete statement of our experimental conditions and methods, and a much fuller statement of their results for the periods covered, are given in the writer's articles in the Annual Reports of the Station for 1910-11 and 1911-12. Persons desiring these reports should apply directly to their state senator or representative.

Altogether, our present results and deductions are derived more or less directly from the results of 13 experiments involving 10 soil types, 12 different locations, 2,653 trees (excluding those strictly on cultural methods), and about 34,610 bushels of fruit in the last 5 years. Only six of these experiments, however, are entirely on fertilization and in bearing. Three of the others, involving 660 trees, are in young orchards, planted in 1908 in connection with these experiments, and the remaining four are primarily on cultural methods, though fertilization is also involved.

The present space permits only the consideration of the more important results from three of the first six experiments, although the results from all six are summarized. These six experiments involve six soil types, 800 trees, and about 11,612 bushels of fruit in the past 5 years.

This bulletin continues the series of bulletins and reports already issued upon these experiments, and it supplements or largely displaces Bulletin 100, issued in June, 1910. It is written primarily to meet the needs of practical orchardists, and hence all unnecessary details and explanations are omitted. In addition to the points named above, some consideration is given to the total plant-food requirements of a productive orchard, and also to the characteristic effects upon yield, growth, color and size that follow the application of the leading fertilizer elements.

THE AMOUNTS OF PLANT FOOD ACTUALLY TAKEN UP BY A MATURE ORCHARD

There is an important need for fertility in any orchard that is actively producing and growing. The actual extent of this need can be approximated chemically by determining the average composition of apple wood, leaves, and fruit, and by applying these figures to what may be considered good annual amounts of these products. This we have done both for apples and for a 25-bushel crop of wheat, with the results shown in Table I. The annual weights for apples are based on a yearly production of 100 pounds each of wood and leaves, and of 14 bushels of apples per mature tree. All these amounts are distinctly less than those actually observed and reported, but inasmuch as they give an annual yield of 490 bushels per acre of 35 trees they are considered sufficient for the present purpose.

Table I.—The Relative Plant-Food Draft of Wheat and Apples.

(In Pounds per Acre Annually, Based on American and German Averages.)

	Wheat Grain	WHEAT (Total)	Wood	Leaves	Fruit	APPLE (Total)
	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
Annual Weights.	1500	4200	3500	3500	24500	31500
Nitrogen (N)....	30.0	43.7	11.3	25.6	16.2	53.1
Phos. Acid (P_2O_5)	10.0	15.8	3.6	5.3	6.4	15.3
Potash (K_2O)....	9.8	26.8	6.6	15.9	41.5	64.0
Lime (CaO).....	0.84	8.0	29.1	29.5	3.0	61.6
Magnesia (MgO).	3.0	6.1	4.4	8.9	3.4	16.7
Iron (FeO)......	.....	.....	0.5	1.5	0.8	2.8

In the first place, it will be noted that in total food draft, the apples exceed the 25-bushel wheat crop in every constituent except phosphoric acid, and in it they fall behind only by half a pound. Notwithstanding this fact, the trees are usually able to maintain themselves much better and longer than wheat. This is probably largely because of their much longer season of root-activity, their more natural demands, [1] the annual return of most of the plant food in their leaves, and their ability to curtail production for one or more seasons when conditions become unfavorable. Without going into details, however, it is quite evident that very important amounts of plant food are annually removed by an apple orchard. Scarcely any soil can furnish all these materials indefinitely in the amounts and times required, and, unless proper assistance is rendered, there must come a time when production is materially reduced and off seasons occur.

Part of the orchard's product requires comparatively small amounts of the important elements. This is notably true of the wood, even when the annual production of mature trees is considered. This largely accounts for the fact that young trees are much less likely to make a profitable response to fertilizer applications than those of bearing age. The younger trees often respond very well to manure or to any satisfactory mulch, as shown in three of our experiments considered elsewhere.[2] This is apparently due more to moisture conservation, however, than to any direct increase in fertility.

Returning to the table, it is of interest to note the relatively large amounts of nitrogen, potash, and lime, and the comparatively small amount of iron annually taken up by the apples. Nearly all the lime remains in the wood and leaves, while a large proportion of the potash finds its way to the fruit.

This large amount of lime seems to have some significance, so far as the wood is concerned, because, as shown later in several of our experiments, its application has resulted in considerable improvement in growth. In the fruit, however, very little lime is required, and hence its application should not be expected to affect the yields materially, and this corresponds with our field results. Moreover the total effect of adding lime alone is surprisingly small, in comparison with the large amounts that are taken up. Either these amounts are merely drawn in and deposited mechanically by the transpiration stream, and hence are largely without physiological significance, or else the average soil is still able to supply the lime needed.

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[1] This is especially marked in the case of the fruit as compared with the demands of the grain in wheat. For further discussion, see article by the writer in the Annual Report of the Station for 1910-11, pages 447 to 449.

[2] See the writer's article on "The Influence of Cultural Methods and Cover-crops on the Yield, Growth and Commercial Quality of Apples," published in the 1913 Report of the State Horticultural Association of Pennsylvania.

With iron the case is very similar. This element is almost universally present in agricultural soils and the total amount required is so small that its addition can scarcely be expected to produce any important effect. This also is borne out by such experimental results as are now available.

In view of the large amount of potash carried by the fruit, one might suppose that its addition to the soil would be very important in improving yields, and this idea has been widely proclaimed especially by those considering only the chemical composition of the fruit. As indicated later, however, it seems that most orchard soils are already sufficiently supplied with potash in available forms and that the chief shortages occur in the nitrogen and phosphates. This is the case notwithstanding the fact that the latter materials are actually required in considerably smaller amounts.

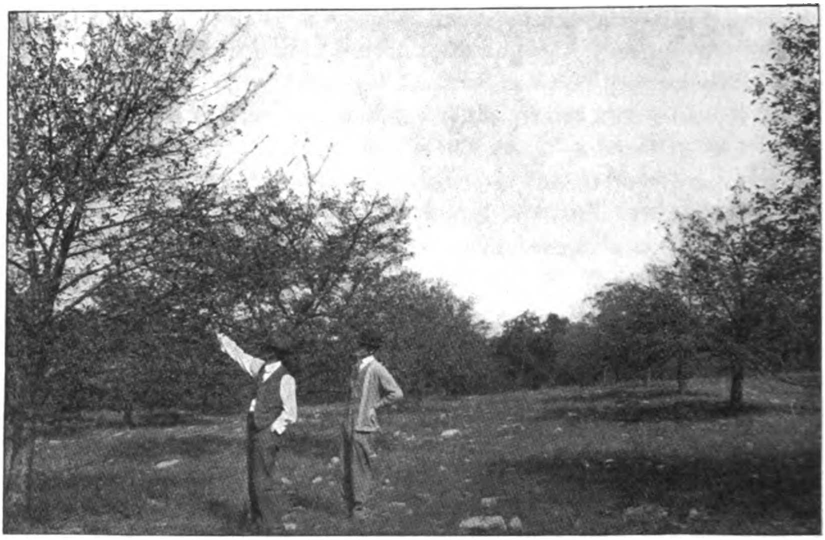

FIGURE 1. A VIEW BETWEEN PLATS 6 AND 7 IN THE BROWN ORCHARD

Plat 7, on the left, is unfertilized but its appearance is as good and its growth and yields have been somewhat better than those of plat 6, which has received phosphate and potash for the past six years. (See Table III, and compare with figures 2 to 5.)

From these facts it is evident that there is comparatively little relation between response and total requirements in the case of plant food and that something more than a knowledge of the chemical composition of the fruit and wood is needed before one can properly fertilize an orchard. Even with the additional knowledge of the composition of the soil, the problem is not much simplified because it is impossible as yet to duplicate sufficiently the conditions existing in any soil. A chemist may determine the total amounts of plant food present, but he can not yet determine their actual availability to the trees with sufficient accuracy to be of much value.

The practical and proper fertilization of an orchard, therefore, becomes an experimental problem, and its solution is dependent primarily upon the pomologist or horticulturist, supplemented by local tests. In other words, the question is not so much what amounts of plant food are annually taken up, nor what amounts are present, but rather it is what responses are made when certain kinds and quantities of plant food are actually added to an orchard soil.

THE EFFECTS OF PLANT-FOOD ADDITIONS TO ORCHARDS

It was to get light on the latter question on several different types of soil, that the present experiments were started by the Pennsylvania Station in 1907. As already stated, however, in the present discussion we shall refer to six of these experiments only, and shall call special attention to but three of them, since they bring out most clearly the leading principles involved.

Rates and Methods of Application.—The rates of application used in the present series of experiments are as follows: **actual nitrogen,** 50 pounds per acre, carried about half in dried blood and half in nitrate of soda; actual **phosphoric acid** (P_2O_5), 100 pounds, carried in acid phosphate, with "floats" and recently basic slag used in certain plats for comparison; **potash** (K_2O), 150 pounds, carried at present in the high-grade muriate, with the high-grade sulphate and recently also the low-grade sulphate used in comparison in certain experiments. The manure is applied at the rate of 12 tons per acre, and the lime at 1,000 pounds per acre. All the applications are made annually. In the Johnston and Brown experiments considered below, the fertilizers are not cultivated into the soil, but are simply spread over the surface and left to be carried in by the rains. They are cultivated into the soil in the Tyson experiment. All fertilizer applications are made somewhat after petal fall, but the manure is put on any time during the spring.

These applications were naturally designed at the beginning of the experiments, before there was any definite experimental evidence as to the most desirable proportions and amounts to use. The amounts now advised for general use are shown later.

Results from the Johnston Orchard.

The following table gives the yields obtained from some of the above applications during the past 5 years. These results are obtained from an experiment with Baldwins, now 24 years of age, located on a Volusia silt loam in Lawrence County, north of Pittsburgh. On first inspection, these trees did not seem to be suffering especially from a lack of plant food, but they had not been bearing satisfactorily and their annual twig growth was averaging only about an inch, with occasional maximum growths of 5 or 6 inches. These rates of growth are continuing on the checks or unfertilized plats, but they have been practically tripled on the plats receiving proper fertilization.

In estimating the influence of the treatments, the yields of the first year are excluded because they can never be materially affected by the applications of the first season. The yields are given in pounds per plat, and also in bushels per acre annually for the last four years.

Table II.—Influence of Fertilization on Yields. (Johnston Orchard.)

(Yields in Pounds per Plat and Bushels per Acre Annually, 1908-1912.)

Plat	1	2	3	4	5	6	7	8	9	10
	Check	Nitrogen & Phos.	Nitrogen & Potash	Check	Phos. and Potash	Comp. Fertilizer	Check	Manure	Lime	Check
	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
1908........	90	528	237	446	57½	759	211	278	558	106
1909........	675	6018	5257	1932	3089	6621	2008	3531	1216	1266
1910........	2575	3265	1822	3168	3552	2108	1629	6149	3185	3505
1911........	283	7563	7816	617	1227	8209	1362	4874	388	106
1912........	1024	1225	696	1382	1385	189	1226	6698	741	474
Total 4 yrs.	4557	18071	15591	7099	9253	17127	6225	21252	5530	5351
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Av'ge yield per acre..	136.7	542.1	467.7	213.0	277.6	513.8	186.7	637.5	165.9	160.5
Gain over av. check*	......	377.9	293.5	......	103.4	339.6	......	463.3	-8.3	......

In the first place, it will be noted that the average yields of the checks, or unfertilized plats, have run fairly uniform, producing an average annual yield of 174.2 bushels per acre during the last four years. Lime alone (at the rate of 1,000 pounds per acre annually) has shown no improvement over the average check and as a matter of fact it has averaged 8.3 bushels per acre less, a deficit that is doubtless largely or wholly due to incidental causes and natural fluctuations. The phosphate and potash combination has affected the yield here rather distinctly. This may be due at least partly to a possible advantage in location, as indicated by the fact that its adjacent check is the highest producer among them and is averaging within 64 bushels of the phosphate-potash treatment. The growth on the latter plat, however, is nearly 3% less than that of the normal unfertilized plat, and its general appearance is not appreciably superior to that of the checks. It is evident, therefore, that these trees are still vitally in need of something, although it will be noted that they are receiving the fertilization commonly advised for orchards,—largely on the basis of chemical analyses. (Compare Figures 1 and 2 in this connection.)

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*The average check or unfertilized plat produced 174.2 bushels per acre annually, during 1909-12.

This need is being quite thoroughly met on the adjacent plat 6, which differs from number 5 only in the addition of nitrogen. The mere addition of nitrogen in this case has more than tripled the gain. Wherever nitrogen appears in the treatments, very large yields are observed, and the foliage and growth of the trees are also very satisfactory,—the average gains in trunk-girth ranging from 25 to 90%.

Plat 2, receiving nitrogen and phosphate only, at the present time shows a better gain than number 6, which receives potash in addition. This is directly connected with the almost complete crop failure that occurred in the latter plat this past season, and it is also doubtless partly attributable again to the natural fluctuations in yield. It shows, however, that no additional potash is needed in this orchard, so far as the yields are concerned.

Phosphates are next in importance to nitrogen here, as indicated by the 42-bushel deficit that occurs on plat 3 as compared with number 6, when phosphorus is omitted in the former, and also by the high yields in plat 2. Manure, as a result of the extra large crop of 1912, when most of the other plats were having an off season, is now in the lead in this experiment, with the tremendous average yield of 637 bushels per acre annually for the past four years. This gives an annual gain over the check of 463 bushels per acre, which is a very satisfactory exchange for 12 tons of manure. This benefit from manure is doubtless largely due to its nitrogen content, the proof of which becomes more evident later.

Time Required for Results to Appear.—It is a common impression that long periods are required to determine the value and kind of fertilizer needed for an orchard. It will be noted here and in the following experiment, however, that both these facts were thoroughly evident in the season immediately following the one in which the fertilizers were first applied. In other words, both the value of fertilization and the kind of fertilizer needed were clearly evident in these two cases within but little more than a single year after the first application, and the general conclusions formulated then have not been materially changed by the results of the 4 or 5 additional years that we now have. In most other cases, also, where these facts did not appear in the first two or three seasons of bearing, they have not appeared in the results of the five or six years that are now available. This is of special importance in connection with the local tests recommended later, though in them we advise at least 3 years of trial, for the sake of greater safety and greater stability in the resulting conclusions.

Results from the Brown Orchard

This experiment is located in Bedford County on DeKalb stony loam,—a residual, foot-hill soil chiefly of sandstone origin, which is widely used for orchard purposes. This soil had been cropped very heavily before the orchard was planted. The trees are York Imperial, now 24 years old. They had borne some fairly good crops before the experiment was started, but they were no longer bearing well except on occasional trees, and their annual twig growth was very small,—averaging scarcely half an inch. This rate of growth has been greatly increased by fertilization, as may be observed to some extent in Figure 2.

The present experiment involves the same treatments as those in the Johnston orchard and four others besides,—those in plats 6, 9, 11 and 12. It also was started a year earlier, in 1907, and the results of that season are excluded in the present table for reasons stated above. The results for the past five years are given in Table III.

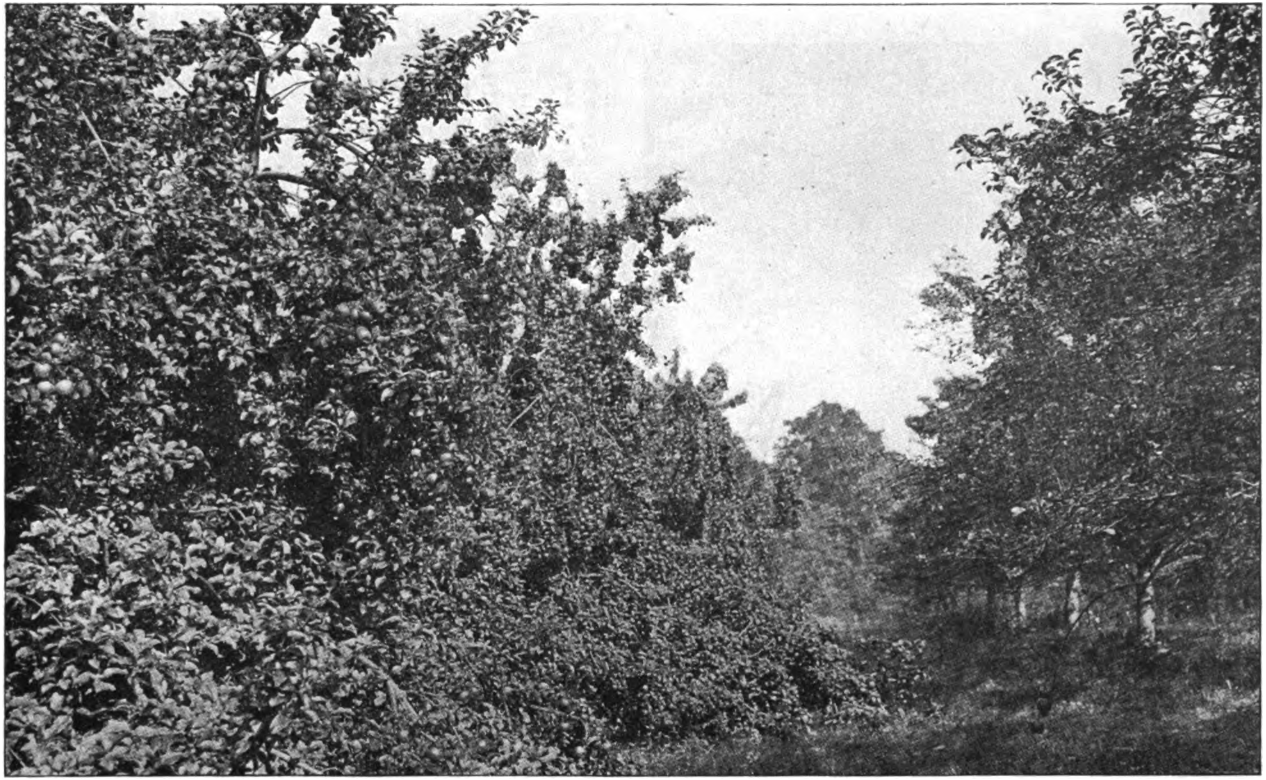

FIGURE 2. NITROGEN AND PHOSPHATES VS. NOTHING, IN EXPERIMENT 220.

The fertilized trees, to the left, have averaged 564.5 bushels per acre annually for 5 years. Their normal unfertilized yield for the same period was 188 bushels. In 1912, when photographed, these trees were bearing at the rate of 1,398 bushels per acre while the adjacent unfertilized plats, 1 and 4, were averaging 73.2 bushels. (See Table III, in connection with Figures 1 to 4.)

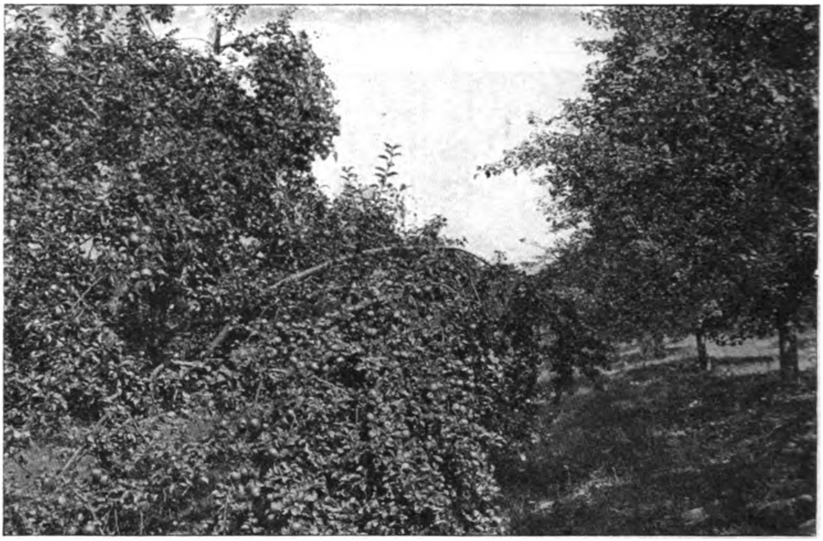

FIGURE 3. NITROGEN AND POTASH VS. NOTHING, EXPERIMENT 220.

The fertilized trees, to the left, have averaged 391 bushels per acre annually for 5 years, while their normal unfertilized yield was 104 bushels. In 1912, they bore 1,086 bushels per acre, while the adjacent unfertilized checks were averaging 73.2 bushels. Also note relative twig-growth.

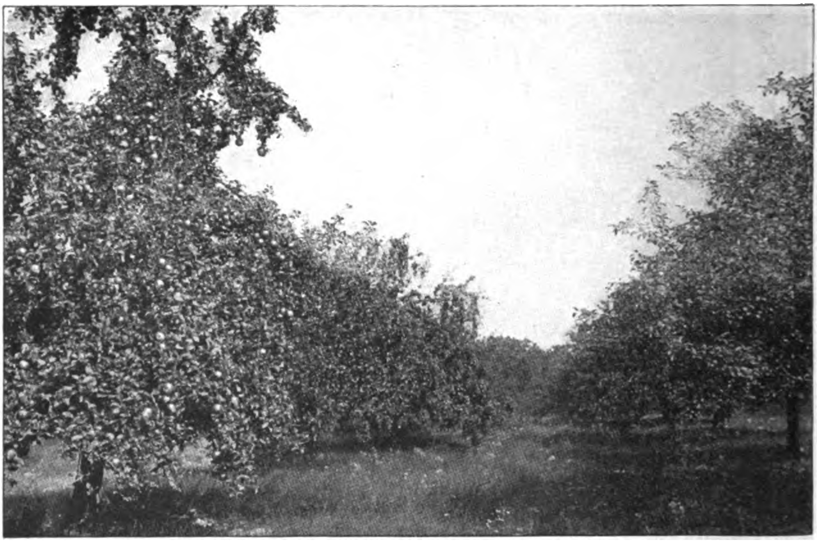

FIGURE 4. COMPLETE FERTILIZER VS. NOTHING, EXPERIMENT 220.

The fertilized trees here have averaged 372 bushels per acre annually, although rather unfavorably situated. The average for the unfertilized plats was 90.2 bushels. The yield of the former in 1912 was 946.7 bushels per acre, while the adjacent checks were averaging 130 bushels.

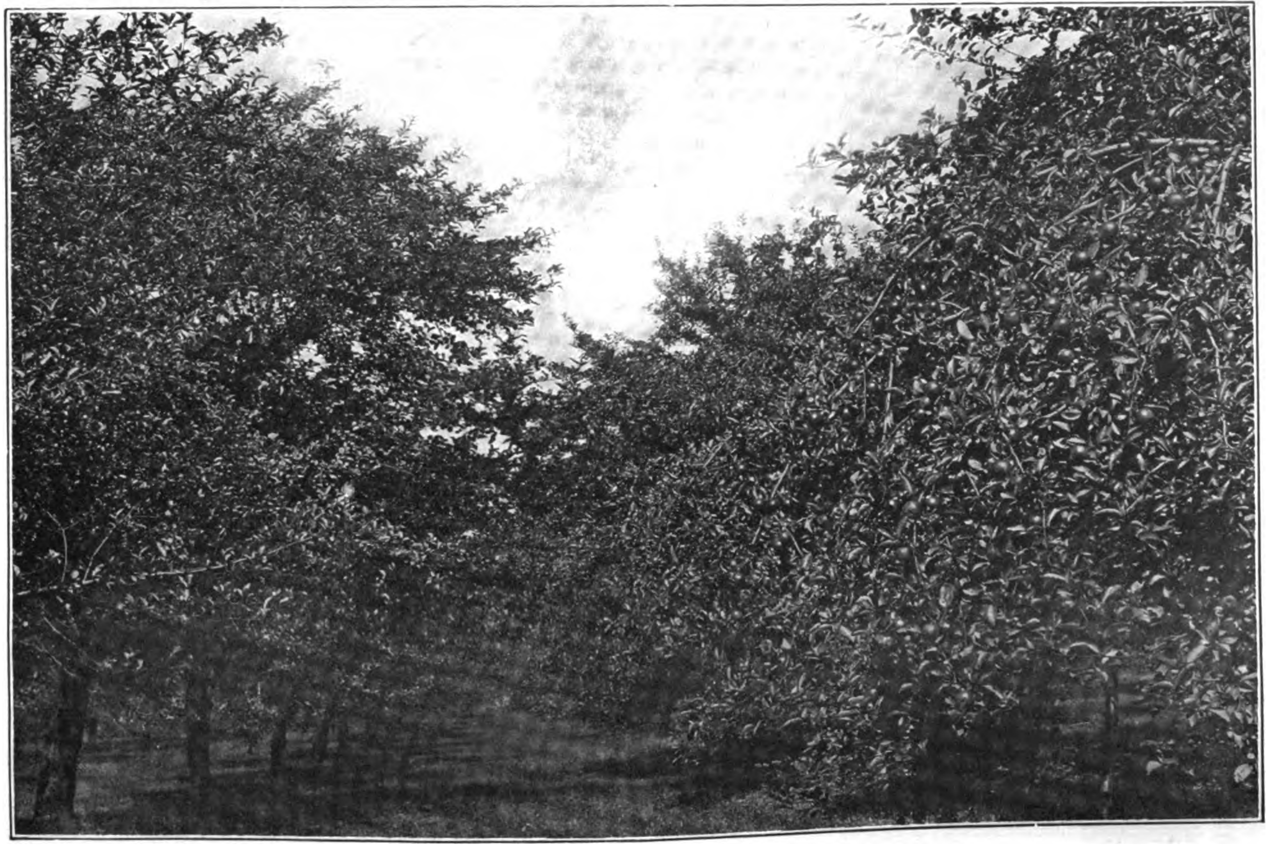

FIGURE 5. NITROGEN AND PHOSPHATES VS. NOTHING, IN EXPERIMENT 338.

A view between plats 1 and 2, considered in Table II. The unfertilized trees on the left have averaged 136.7 bushels annually for 4 years. Those on the right, differing only in the addition of fertilizers, have averaged 542.1 bushels per acre during the same period.

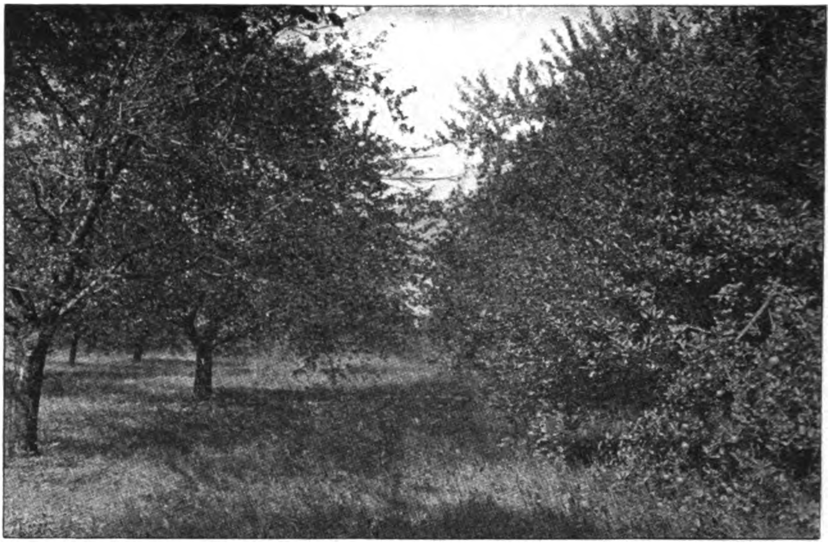

FIGURE 6. STABLE MANURE VS. NOTHING, EXPERIMENT 338.

The unfertilized trees of plat 7, partly shown on the left, have averaged 186.7 bushels per acre for 4 years, while those on the right, differing only in the addition of manure, have averaged 637.5 bushels. Note the difference in twig-growth and general density of the trees.

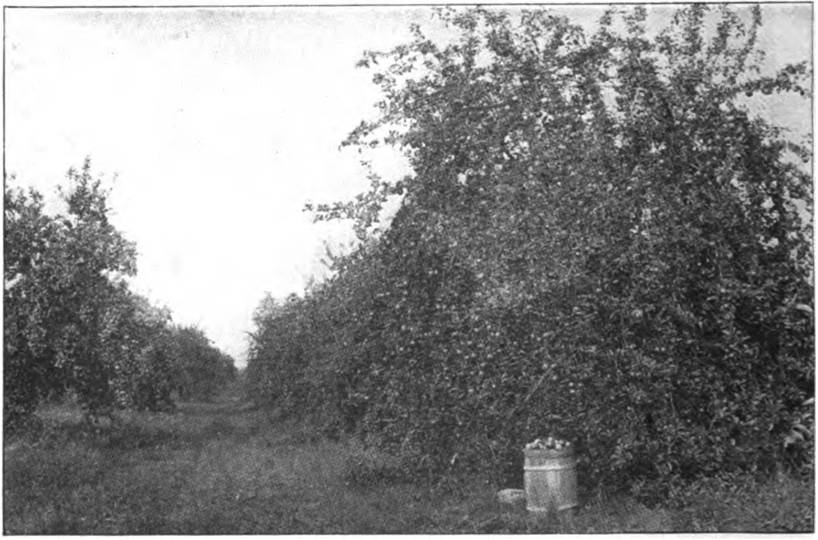

FIGURE 7. EFFECT OF THE GENERAL FERTILIZER, RECOMMENDED IN TABLE VI.

Tompkins King and other varieties showing the value of our general orchard fertilizer in other parts of the Johnston orchard. These trees had not borne well before fertilization, but this is their third successive crop.

Table III.—Influence of Fertilization on Yield. (Brown Orchard.)

(Yields in Pounds per Plat and Gains in Bushels per Acre Annually During 5 Years.)

Plat	TREATMENT	1908	1909	1910	1911	1912	Totals	Benefit over Normal	Gain over av. Check*
		Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	%	Bu. per A
1	Check	2402	25	4052	1588	453	8520	......	......
2	Nitrogen & phosphate	4153	588	5920	2219	7281	20161	204.8	376.5
3	Nitrogen & potash	3079	78	3838	1567	5402	13964	196.6	259.2
4	Check	754	9	470	1260	309	2802	......	......
5	Phosphate & muriate	1014	252	2381	1643	616	5906	79.9	75.2
6	Phosphate & sulfate	292	266	1368	1299	356	3581	-4.8	10.1
7	Check	254	192	1115	1568	1117	4246	......	......
8	Nitr., phos. & potash	1219	454	2436	3241	4931	12281	208.7	253.7
9	Nitrogen	863	1575	120	3082	1614	7254	96.-	113.0
10	Check	458	515	787	1448	222	3430	......	......
11	Acid phosphate	104	892	787	794	64	2641	-25.9	-16.2
12	Raw phosphate	100	124	581	703	123	1631	-55.9	-35.5
13	Check	266	257	2096	498	727	3844	......	......
14	Manure	621	1947	778	7334	1117	11797	273.9	240.2
15	Lime	152	160	1029	1060	288	2689	9.0	-14.8
16	Check	246	36	943	387	166	1778	......	......

In general, we have the same types of results here as in the preceding experiment,—large gains from nitrogen, phosphates and manures, with relatively small effects from potash, and again no advantage at all from lime. There are greater irregularities in this experiment, owing somewhat to its greater size, but chiefly due to the presence of a woods on the mountain side above the first check plat, from which the latter is separated by a single row of trees. The leachings from the floor of the woods have acted much like a nitrogen fertilizer, and as a result the trees nearest the woods, although of the same age as those farther down, are considerably larger, thus accounting for the greater yields of the first 2 or 3 plats. This influence practically disappears, however, before the fourth plat is reached, as shown by its low yields which are those of a typical check.

The differences observed in the last two columns are due partly to these irregularities, partly to a certain amount of leaching and cross-feeding on the part of some of the checks in spite of separation rows below each treated plat, and partly to a different method of calculation. In one column, the benefit is figured on the basis of the normal production of the immediate plat concerned, which method is supposed to eliminate soil irregularities to the greatest possible extent. When the adjacent checks are being benefited by leachings or cross-feeding, however, this method fails to show the full benefit due to the treatment. This failure is especially evident in plat 6 which shows an apparent negative influence in the "normal" column and a positive influence of ten bushels per acre annually in the column based on the average check. The apparent negative influence can be traced directly to the extra yields of certain trees in the adjacent check plat 7, which is apparently receiving some benefit from plat 8 as a result of cross-feeding. The same thing appears in the negative figures shown by plats 11 and 12, although they are not entirely eliminated by using the average checks as the basis. The average check itself is not entirely free from the cross-feeding influences, since it only distributes their extra yields, and hence it is probable that the negative figures in plats 11, 12 and 15 of the last column merely indicate that these materials have no definite influence when applied by themselves.

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*The annual gains over their "Normal Production" are indicated in plats 2 and 3. Their annual yields were 564.5 and 391. bushels per acre, respectively. The average check, omitting No. 1, was 3,220 pounds per plat or 90.16 bushels per acre annually.

Returning now to the results themselves, and especially to those treatments not included in the preceding experiment, we may note first that the muriate of potash in plat 5 has given much better gains than the sulphate in the adjacent plat. This is contrary to the results of the Massachusetts experiment, but similar results are now being shown in all our experiments wherever this comparison occurs. Hence the difference in the Massachusetts experiment would seem to be due to something other than the difference in potash carrier. At present, therefore, we believe that the muriate is at least as efficient as the sulphate, and in view of the facts that it is cheaper, more soluble, and much less subject to "caking" in the mixtures, we are now using and recommending it for apples.

In plats 11 and 12, and in similarly treated plats of our other experiments, we see the apparent futility of attempting to improve yields materially by applying phosphates alone. This is not due to the fact that phosphorus is not needed, nor can it be largely attributable to the absence of cultivation, as may be seen by comparing the results in plats 9 and 2. Nitrogen by itself in No. 9 shows an annual gain of 96% or 113 bushels per acre, but when phosphorus is added in plat 2 these benefits are more than doubled. Phosphorus as usual, therefore, appears to be next in importance after nitrogen in improving yields.

The Permanence of Fertilizer Influence.—It is another fairly common impression that the influence of fertilizers is transient and that, even where their effect is favorable at first, this effect soon wears out and may leave the soil worse than before. This evidently depends very largely on the character of the fertilization, and in this respect apples are not different from other crops. If the gains are induced by some caustic action of such materials as gypsum or lime when used alone, this may actually be the final result.

On the other hand, it should be noted that in plats 2, 3 and 8, where definite plant foods are being supplied, the effects of fertilization were greater in 1912, the sixth year of the experiment, than ever before. The steadiness and regularity of the increases also are especially notable in plat 8, which shows a distinct gain in every year except 1909, and in that year the yield would have been fully 1,000 pounds greater had there been sufficient moisture available to properly develop the fruits that were actually present.

In plats 2 and 3, only two fertilizer elements have been applied, and also the yields have been so large in the evenly numbered years that it was impossible to prevent some alternation with lighter crops in the odd years. This same general condition is evident to a considerable extent in the Johnston orchard. In other experiments, however, and especially in one primarily on cultural methods in the Fassett orchard, with proper fertilization and with crops ranging from 200 to 600 bushels per acre, we have had steady yields on Baldwins and Spies, similar to those in plat 8, which have been maintained for a period of five years without any important decrease appearing.[3]

The unusual size of the 1912 crops on plats 2 and 3 in the Brown experiment deserves special attention. While their adjacent checks, 1 and 4, were showing an average yield of 73.2 bushels per acre, plats 2 and 3 were producing the tremendous average of 1,217.5 bushels per acre, and 1,006 bushels of this were picked fruit. The terminal twig growth of the checks, also, scarcely averaged half an inch for the season, while that of the fertilized plats, in spite of their enormous crops, averaged from 6 to 8 inches, with frequent terminals running up to 2 feet. All these differences were brought about solely as a result of differences in fertilization. The spraying, pruning, soil management, variety and age of trees, and all other visible features were just the same on the checks as on the fertilized plats. Some idea of the differences shown by the fertilized and unfertilized plats in this experiment may be obtained from Figures 2 to 4.

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[3] See Table XII in the writer's article in the 1913 Report of the State Horticultural Association of Pennsylvania.

Results in the Tyson Orchard

In the two preceding experiments, we have seen very large annual gains resulting from certain fertilization, particularly that rich in nitrogen and phosphorus, regardless of whether these elements were carried in manure or in commercial forms. In these cases also, the gains from potash were relatively small or entirely absent. Thus far in the Tyson experiment, so far as the yields are concerned, we have practically the reverse conditions.

The trees in the latter experiment are much younger, being now but 14 years of age. The varieties are York Imperial and Stayman Winesap, the latter having been top-worked on certain York rows about 6 years after planting. The soil is a relatively heavy silt loam, and tillage and annual cover-crops have been maintained near the trees practically uniformly since the orchard was started. The annual growth and general appearance of all the trees in this experiment are much better than those of the average check trees in the preceding experiments. Practically no fruit had been borne by these trees when our experiment was started in 1907, and there has been but one fairly full crop since then,—that of 1911. The treatments are the same as those in the Brown experiment and the results are shown in Table IV.

Table IV.—Influence of Fertilization on Yield and Growth in the Tyson Orchard.

(Yields in Pounds per Plat, 5 years, and Gains in Bushels per Acre Annually, Last 3 Years.)

Plat	TREATMENT	1908	1909	1910	1911	1912	Totals	Benefit over Normal	Gain over av. Check	Growth Gain over Norm'l 6 yrs.
		Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	%	Bu. per A	%
1	Check...............	14	95	346	2053	549	3057	......	......	......
2	Nitrogen & phosphate	26	73	301	2277	464	3141	8.0	12.2	7.4
3	Nitrogen & potash ...	43	115	418	3043	542	4161	50.9	43.0	17.7
4	Check...............	21	54	260	1555	719	2609	......	......	......
5	Phosphate & muriate	26	146	476	2828	495	3971	46.1	36.5	8.1
6	Phosphate & sulfate .	61	179	483	2352	975	4050	43.2	36.8	2.3
7	Check...............	18	45	235	1777	862	2937	......	......	......
8	Complete fertilizer...	21	74	300	2885	190	3470	26.7	22.9	12.7
9	Nitrogen	17	83	229	1746	551	2626	3.5	-4.7	7.9
10	Check...............	17	89	150	1579	504	2339	......	......	......
11	Acid phosphate......	3	43	153	1359	655	2213	-9.8	-15.8	4.4
12	Raw phosphate......	4	62	164	2010	842	3082	20.0	11.4	0.8
13	Check...............	31	46	103	1886	615	2681	......	......	......
14	Manure	15	52	190	2333	262	2852	4.1	4.-	14.6
15	Lime (& fertil'r, 1912)	27	86	186	1765	1113	3177	13.4	13.1	-1.6
16	Check...............	10	76	115	1922	739	2862	......	......	......

As already noted, the relative youth of these trees makes both their yields and differences much less than those in the preceding experiments. With increasing age, it is probable that some of the results may be different, especially in view of the relative growth that is now being made under the different treatments. At present, however, certain facts are of interest.

In the first place, the practical failure here of both manure and nitrogen is quite remarkable. The regular annual application of 12 tons of stable manure, in this case, has resulted in an annual gain of less than four bushels of apples per acre. During the same time, nitrogen alone has shown no gain at all, and nitrogen and phosphates, which were so effective in the preceding experiments, here show an annual gain of only 12 bushels per acre,—not enough to pay for the treatment.

Potash, on the other hand, in direct contrast to its effect in the experiments above, here shows a distinct gain in yield wherever it is applied. The best of these gains,—the one in combination with nitrogen,—is only 43 bushels per acre annually, but this is more than a 50% increase over the normal yield, and it shows a fair profit over the cost of treatment, besides giving over 17% of an increase in growth. Potash applications therefore, have evidently been of value in this orchard, even when those of manure and of nitrogen and phosphates were largely failing.

The Action of Manure vs. that of Commercial Fertilizers.—The above facts, taken in connection with those shown in the two earlier experiments, indicate that the plant-food action of manure is practically identical with that of a commercial fertilizer rich in nitrogen and phosphates. It also apparently indicates that the potash in the manure may be less readily available than that carried in commercial forms. The old controversy over the relative value of manure and commercial fertilizers, therefore, is without any particular significance, so far as plant food is concerned. Either type of fertilizer may be successful or either may be a failure, depending upon the particular conditions involved.

The manure, however, often has some additional value as a result of its mulching effect. This naturally can not be duplicated by commercial fertilizers alone, though it may be duplicated by any other kind of mulch, as has been shown especially in our Experiment 339 in Bradford County, and also in most of our cultural method experiments. (See reference in foot-note 2.) The matter of availability also is often important, as manure cannot always be secured, and it is for this reason that the relation between manure and nitrogenous fertilizers should be well understood. Moreover, it sometimes happens that large and regular applications of manure result in a distinct increase in the amount of blight, and also in an undue increase in the size of the fruit and in the amount of punky pitting in the latter. In such cases, a reduction in the applications or the partial or complete substitution of a proper commercial fertilizer is desirable.

A Summary of Fertilizer Influences on Apples

It is impossible in the present space to consider all our experiments singly, to the extent done with the three just considered. Before passing to the last stage of our discussion, however, it seems desirable to present a brief tabular summary of the fertilizer influences shown in six of the experiments, including the three just considered. This summary shows the calculated influences of the various fertilizer elements on the four most important characteristics of apples, viz., their yield, color, average size and amount of wood-growth. The relative values of the different elements during a five-year period, in terms of benefit over the normal results obtained without fertilization, are shown in Table V.

Table V.—Influence of Fertilizer Elements on Apples.

(Average Benefits over the Normal Results without Fertilization 1908 to 1912.)

(a) Expts. 215, 216, & 220	Yield	Color	Size	Growth
	%	%	%	%
Nitrates in combination ...	62.7	-11.6	-0.7	10.43
Nitrates alone	32.5	-12.7	-4.3	15.51
Phosphates in combination	20.2	- 2.1	0.3	2.28
Phosphates alone..........	-10.7	2.7	-0.6	2.45
Potash in combination	15.1	3.2	5.8	3.67
Complete fertilizer.........	78.3	-15.4	5.2	17.67
Manure	75.9	-11.4	5.8	29.07
Lime alone.................	- 8.24	- 0.3	-2.0	6.31
(b) Expts. 336, 338, & 339	1908–12	1909–12	1909-12	1908–12
Nitrates in combination ...	74.5	-12.7	-0.4	27.00
Phosphates in combination	33.5	- 2.8	4.9	- 0.23
Potash in combination	- 3.6	1.4	7.1	2.79
Complete fertilizer.........	80.5	-15.6	5.2	29.63
Manure	168.8	-15.9	25.2	37.34
Lime alone.................	29.8	- 5.4	15.9	15.48

Without going into details it may be noted that in general the same influences that have materially increased the yields have also increased the growth. In other words, our best growing plats have as a rule been our best fruiting plats. On sound, healthy trees, this will generally be the case unless either occurs to an abnormal extent, in which case the other may be somewhat reduced. Mild injuries may also stimulate yields at the expense of growth.

In Table V, the most marked exception to the present rule appears in the case of the phosphates, especially in the lower section of the table. This may be connected with the fact that the old wood especially is very low in phosphoric acid, as shown in Table I, and our present definite growth determinations are based upon increase in trunk-girth alone. On twig growth, however, our observations indicate that phosphate additions have been very helpful, particularly in the Brown orchard. This also tends to bring it in line with the general rule just stated.

The Control of Average Size.—So far as fertilization is concerned, manure and potash are the only materials that have consistently benefited size. The influence of manure is doubtless very largely due to its mulching or moisture-conserving effect, since moisture makes up about 84.6% of this fruit, on the average.[4] The potash influence also, so far as it is a definite benefit, is probably brought about through the same medium, inasmuch as potash is credited with some ability to increase the osmotic power of the cells, thus enabling them to compete more successfully for whatever water is present.

There is also a distinct possibility that the apparent benefit of potash on size may be largely due to the fact that it is associated with much lower yields than the other materials, especially nitrogen. Conversely, their failures to increase size may likewise be due to their association with markedly increased yields.

This brings out the general proposition to which we have called definite attention elsewhere, [5] that with a normal moisture supply and sufficient growing season, the dominant influence controlling size in apples is the number of fruits on the tree, after this number has passed a certain optimum or "critical point." This point, however, is relatively high, our data showing that even on trees up to 15 years of age, little or no correlation appeared until the number of fruits had reached 1,400 or more per tree. Above this point, proper thinning is the most important means of increasing the size of the fruit. Below it, the size can usually be markedly affected by moisture supply, cultural methods, manure, and possibly by fertilizers,—especially those rich in potash. The latter factors may also co-operate in such a way as materially to raise the critical point. In general, however, proper thinning and moisture conservation are the most important means of improving fruit size.

The Control of Fruit Color.—In Table V, it will be observed that none of the fertilizer treatments has resulted in any marked improvement in color. Slight and irregular benefits are shown by potash and by some of the phosphate applications, but nothing of any importance. The same is true of iron applications, so far as experimental evidence is concerned.

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[4] See Table XVIII in the writer's article in the Annual Report of the Station for 1910-11, page 435.

[5] See article referred to in footnote 4, pages 500-503.

These facts again lead up to the general propositions that color in apples cannot be materially increased by fertilizer applications, and that their red colors are essentially dependent upon maturity and sunlight. Conditions that tend to increase one or both of the latter factors, such as late picking, open pruning, light soils, and sod culture tend to increase the red color. Opposite conditions decrease it.

These propositions make it clear why the nitrates and manure apparently injure color. It is simply done by retarding maturity and diminishing the available sunlight, as a result of the increased density of foliage. To determine the truth of this, in 1911 we left the fruit on the nitrate plats in the Johnston orchard until it had reached approximately the same degree of maturity as that attained by the checks when their fruit had to be picked on account of dropping. The delay required was fully three weeks,—from September 29 to October 19,—and even then the later fruit was picked with much more difficulty than that on the checks, besides showing a much lower percentage of fruits dropped. The amount of color on the nitrate plats at the later date was actually greater by 10% than that shown on the checks at the time of picking.

The occasional marked increase that sometimes occurs in color as a result of spraying is largely explainable on similar grounds The sprays reduce the worminess and thus enable the fruit to remain longer on the tree. It also may reduce the amount of foliage somewhat, as a result of spray injury, thus permitting more light to reach the fruit. In general, however, in improving color, chief reliance must be placed on those methods that tend definitely to secure fuller maturity on the trees and to get the maximum amounts of light to the fruit.

APPLYING PRESENT DATA TO INDIVIDUAL ORCHARDS

In the three experiments discussed separately above, it was noted that the materials found most valuable in the first two were failures in the third, and vice versa. In still other experiments, we can show cases where no form of fertilization has yet shown a profit. These and other experiments prove conclusively the local nature of the problem. Hence even the experiments of others can offer no more than general advice on the fertilization of a particular orchard.

This advice can doubtless be made more exact after a personal examination of the orchard concerned, by one who is familiar with orchard fertilization work, or it may be done with greater certainty if the owner will note and look for some of the more important characteristics of orchards needing fertilization. The latter are best observed in late summer and fall.

In general, the characteristics of an orchard that is certainly in need of a fertilizer are those of starvation. They are usually sufficiently familiar to need no extended description. They are found most commonly in the older orchards, especially in those that have once borne well but are no longer doing so, although still fairly free from important diseases or improper drainage. The foliage is sparse and pale in such orchards, and the annual growth stops early and averages short,—often not more than a half inch, and from this it may range up to two or three inches. In such cases, one can usually apply fertilizers rather liberally with practical confidence of profits, provided the varieties and general handling are right. Even in such an orchard, however, it is advisable **to leave a small typical portion unfertilized** to really determine the value of the treatment.

Under the opposite conditions, such as obtain in most young orchards or in any orchard that is still growing and fruiting well, and retaining its foliage until late in the season, fertilization is much less likely to show a profit. Even in these cases, however, there is often enough probability of benefit **to warrant a limited trial of fertilization, but only over a relatively small area,** and with most of the orchard left unfertilized as a check.

These trials are especially necessary, in the intermediate orchards,—those on the zone lying between the two extreme types just described. Occasionally this intermediate type will respond very strongly to fertilization without necessarily showing the characteristic marks, as is practically illustrated in the Johnston orchard.

A General Fertilizer Recommendation for Apples

For preliminary use in orchards that are apparently in need of fertilization, on the part of those who are unable to carry out such a local test as is shown later, we are now recommending the general fertilizer indicated in Table VI. The fertilizers are stated in amounts per acre rather than in amounts per tree, because of the varying numbers of trees that are planted on an acre. The amounts per tree are readily obtainable, however, by dividing the present amounts by the given number of trees per acre. For young trees, these amounts may be reduced approximately in proportion to the area of soil covered, making this area correspond with the lateral distribution of the roots so far as possible.

Table VI.—A General Fertilizer for Apple Orchards

(Amounts per Acre for Bearing Trees)*

Nitrogen 30 lb. (N)	**Phosphoric Acid** 50 lb. (P_2O_5)	**Potash** 25 to 50 lb. (K_2O)
Carried in: **100 lb. Nitrate and** **150 lb. Dried blood** **or in** **150 lb. Ammonium sulphate**	**Carried in:** **350 lb. Acid phosphate** **or in** **200 lb. Bone meal** **or in** **300 lb. Basic slag**	**Carried in:** **50 to 100 lb. Muriate** **or in** **100 to 200 lb. of low-grade Sulphate**

This table means that a fertilizer carrying about 30 pounds of actual nitrogen, 50 pounds of actual phosphoric acid (P_2O_5), and 25 to 50 pounds of actual potash (K_2O) should be applied on an acre of bearing trees. Where potash is not known to be lacking, the smaller amount may be used, or after a little testing it may even be omitted entirely. With the smaller amount of potash, the essentials of the present combination are carried in 500 pounds of a 6-10-5 fertilizer or its equivalent. In the usual ready-mixed fertilizers, the nitrogen is likely to be carried in ammonium sulphate, with which some liming may be necessary if many applications are made, and especially if leguminous cover crops or permanent covers are desired. In special or in home-made mixtures, the various elements may be carried in any of the materials indicated in the table.

In the work of this Station, the nitrogen is carried in the combination of nitrate of soda and dried blood indicated in the table. This combination carries about equal amounts of nitrogen in each material, and it thus gives a quick action as well as one that is prolonged well through the season. The nitrogen, being the costliest and most active ingredient, requires close watching and possible variations in amount, in order to get the most out of it. It may also be secured, wholly or in part, by the use of stable manure or leguminous plants where they are available. In the case of the other carriers indicated in the table, we have very little evidence on their relative values as yet and hence those that are actually least expen-

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***For young orchards, reduce these amounts in proportion to area covered.**

sive or most convenient should be chosen. All applications should be made annually, subject to the variations indicated below.

Time and Method of Application.—The time of application we believe to be of distinct importance, especially in the case of nitrates. While our evidence on this is by no means complete, yet there are good indications that nitrates can easily be applied too early in the season and thus be wholly lost to the trees. Other evidence leads to the opinion that distinct harm may result from their application about fruit-setting time,—especially in the case of the peach. We feel, therefore, that the nitrates should be applied not earlier than petal-fall in apples and probably not later than the middle of July. In general, about the middle of this period should do very well, though some of our most striking results have come from applications made as late as the 8th of July.

With the peach in Missouri, Dr. Whitten reports that the time of application is very important and that large increases in yield have been obtained from moderate quantities of nitrate of soda alone, when "applied at the right time."[6] This is considered to be "after the main length-growth has taken place in the early summer." Such applications kept the trees from going into the rest period too early, and maintained a green and healthy condition throughout late summer and autumn without renewing the growth in twig length. It may also be noted that in the English work, at the Woburn Experimental Fruit Farm, July applications proved beneficial, while those made in February were of no avail.

An incidental advantage of the delayed applications appears in the fact that it gives an opportunity to vary the rate somewhat in accord with the size of the crop set on the trees. When the crop is light, much smaller applications are required, because of the natural tendency of the trees to develop a sufficient number of fruit buds in the off season. In the full years, on the other hand, the applications should be rather liberal, in order to prevent the total absence of a crop the following year and in the long run to steady the yields. Proper utilization of such a plan as this should save much in a series of years, and also enable one to secure the maximum return for the fertilization applied.

In the case of the mineral ingredients, with their lower solubility and slower action, the time of application is less important.

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[6] **See Proceedings of the Society for Horticultural Science 1911 p. 37.**

Some careful observers in commercial work regularly apply their phosphates and potash in the fall, on their peach orchards, and believe that this gives best results. Thus far, however, we have felt that the time of application for the minerals is of relatively little importance, since they are rather quickly fixed in the soil, in any case, and they do not leach readily. We therefore apply them along with the nitrogen at the time considered best for it. Manure also can be applied at almost any time, excepting possibly late summer or fall, without danger of loss or of ill effects.

The method of application that we have followed is merely to scatter the fertilizer or manure broadcast over the surface of the ground, taking care not to get it too close to the tree trunk, where there are few absorbent roots, and extending the applications well out beyond the spread of the branches. To conform more closely with the distribution of feeding roots, the rate of application is made heaviest in the central part of this area, or in general it is applied most heavily under the outer two-thirds of the spread of the branches. This fertilization may either be left on the surface to be washed in by the rains or it may be harrowed or lightly plowed into the soil. With all this done, it should be remembered that the fertilizer applied in any given season can hardly materially affect the yield of that year, since the fruit buds are formed in the latter part of the preceding season. Important results therefore should not be expected before the following season, at the earliest, and as indicated in some of our experiments, they may not appear until considerably later and still prove of value.

Determining the Actual Needs of an Orchard

The general fertilizer formula indicated above is for use only until the exact needs of the particular orchard can be determined. In other words, it is intended only to meet the immediate demands. If in the meantime one wishes really to answer the question of how to fertilize his own orchard, he can do so by following the plan outlined in Table VII. This plan is especially adapted to the needs of commercial orchardists and to "community" tests on the part of the smaller growers. Like other things of value, a test of this kind requires some work, but as yet it is the only way that one can become really acquainted with the needs of his orchard, and where the income from the latter is important, the time thus spent should be most profitable.

Table VII.—Plan for Local Orchard-Fertilizer Test

(Pounds for a Mature Tree in Bearing.)

1	Check (Unfertilized).
2	Nitrate, 2½ lb.; Dried blood, 3½ lb.; Acid phosphate, 10 lb.
3	Nitrate, 2½ lb.; Dried blood, 3½ lb.; Potash, 2 lb.
4	Acid phosphate, 10 lb.; Potash, 2 lb.
5	Check.
6	Nitrate, 2½ lb.; Dried blood, 3½ lb.; Acid phosphate, 10 lb.; Potash, 2 lb.
7	Same as VI, plus lime, 12 to 25 lb.
8	Manure, 400 lb.
9	Check.

This test should be located in a typical part of the orchard, and should include not less than 5 averge trees of the same variety and age, in each plat. All the trees should be labeled and carefully measured at a fixed point on the trunk, and definite records of their growth and yields should be kept for at least 3 years. Frequently, good indications of the orchard's needs may be obtained in less time than this, as shown above in the Johnston and Brown orchards, but at least this amount of time should be allowed and more should be used when necessary.

The same time and methods of application should be followed as described above. The materials are indicated here in amounts per bearing tree instead of per acre as above, and the same proportionate reductions should be made for younger trees. In other words, if only a third of the ground is to be covered, then only about a third of these amounts should be used, if the rate of application is to be kept within proper bounds.

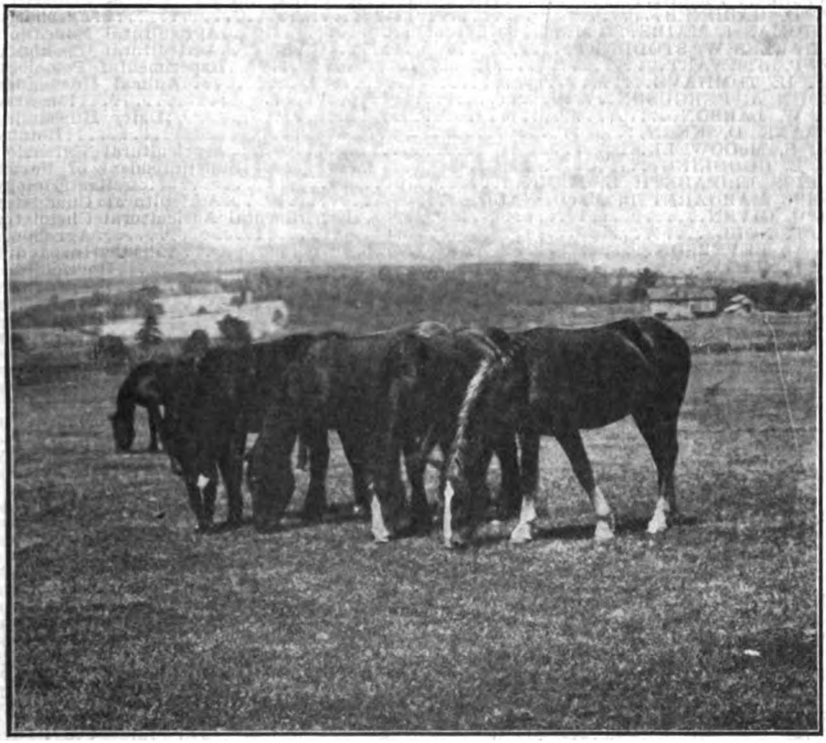
These general suggestions, together with the exercise of proper judgment on the part of the grower, are entirely sufficient to carry this plan to a successful conclusion and definitely settle the fertilizer needs of any ordinary orchard within a few years. If additional suggestions and precautions are desired, however, they can be found in the Annual Report of the Station for 1910-11, pages 409-11. In addition, it should be remembered that an orchard may not show the need of a fertilizer when young, but may develop this need later, especially when heavy bearing is reached. This means that the cases that appear negative at one time may often need further tests and observations later.

J. L. Montgomery
Baldwin

Sci 1638.5.4

The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 122



DEVELOPING DRAFT COLTS

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
JULY 1913.

AGRICULTURAL EXPERIMENT STATION
THE PENNSYLVANIA STATE COLLEGE

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The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 122

DEVELOPING DRAFT COLTS

By W. A. COCHEL and B. O. SEVERSON

The general practice of Pennsylvania farmers in buying rather than producing horses for farm work is justified by the statement that horses can be bought cheaper than they can be produced under eastern conditions. During October, 1910, The Pennsylvania State College and Experiment Station purchased a group of ten grade Belgian and Percheron colts and one pure bred Percheron for use in live stock judging classes. An accurate record of the initial cost, feeds consumed and changes in form has been kept in order that some definite information as to the cost of developing draft colts from weaning to maturity might be available for farmers, investigators and students. The handling of animals in this way is probably more expensive than handling them for market purposes but it has an advantage in that the results are not apt to prove misleading when applied to farm conditions.

Care and Management

First Winter, November 12, 1910—April 19, 1911.

During the first winter the colts were divided into two groups, one of four, the other of six individuals, and allowed to run loose in two large box stalls. They were turned out twice daily for water, and occasionally led from the College Barn to the Agricultural Building, a distance of one-quarter of a mile, for use in the class room. Otherwise they had no exercise, as suitable enclosures were not available. Each group was fed a ration of five pounds per head daily in two equal feeds from a grain mixture of five parts shelled corn, three parts oats, two parts wheat bran, one part linseed meal, weighed and mixed in bulk. This amount of grain was fed until the end of the third month, when it was increased to seven and one-half pounds per head daily. No further increase was made throughout the winter. During the first half of the winter the group of four colts received a roughage ration of corn silage in the morning and hay in the evening. The average amount consumed per head during this period was 8.2 pounds of silage and 7.4 pounds of hay. The other group received the same grain ration and 10.6 pounds of hay without silage. During the last three months of the winter period the grain was increased to 7.5 and the hay to 13.1 pounds per head daily in each group. With this method of feeding, all the colts came through the winter in excellent condition of flesh, having gained 244.27 pounds per head during the winter feeding period of 168 days.

Summer Feeding Period, April 19—November 2, 1911.

The summer feeding period included 196 days, starting April 19 and ending November 2, 1911. All colts were placed in pasture lots on May 4; five days later the fillies were removed to a larger pasture and allowed to range during the day and were placed in the barn lot at night. The four stallions were kept in a small pasture of four acres and were allowed to stay only 4 to 6 hours daily in this lot. The amount of grass was limited, and was therefore supplemented with grain and hay for all the colts. The larger portion of the hay was consumed by the four stallions. The pasture was supplemented to some extent with a soiling crop of green, mixed hay. During the last two weeks of August the four stallion colts were kept in the pasture lots at night, and tied in the barn during the day, in order to protect them from heat and flies.

Seven pounds of grain mixture were fed to all colts up to May 9, at which time the fillies received oats. The stallions received the grain mixture up to May 26, when oats was substituted. The stallions consumed their full complement of feed, but the fillies, due to being on better pasture, consumed only three to five pounds of oats per head daily, until the latter part of August when they consumed eight pounds.

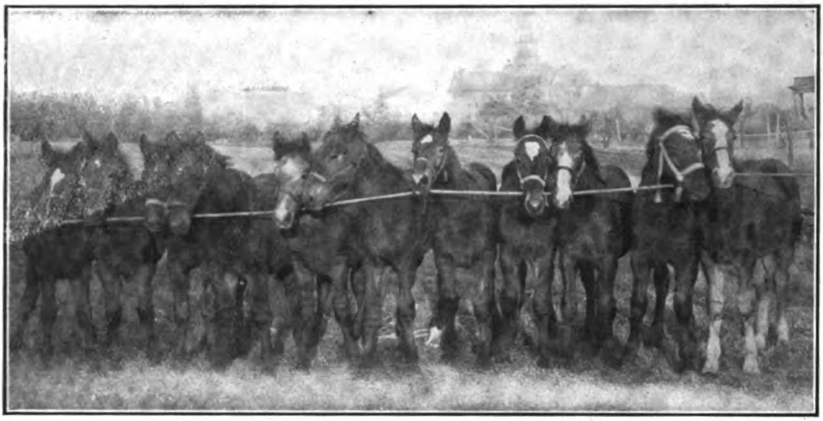

Fig. I. Colts at beginning of feeding experiment (front view).

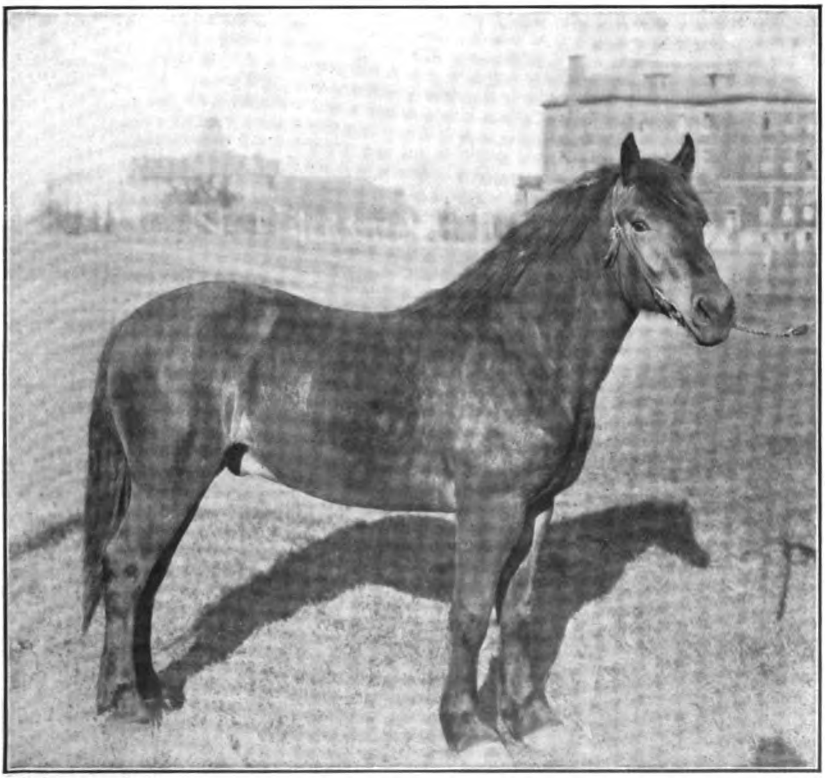

Fig. V. Colt No. 31. Grade Percheron colt of light draft type, foaled May 5, 1910. Weight 1215 pounds, April 19, 1912. An excellent head, neck, shoulders, back and loin, with quality that insures freedom from blemishes.

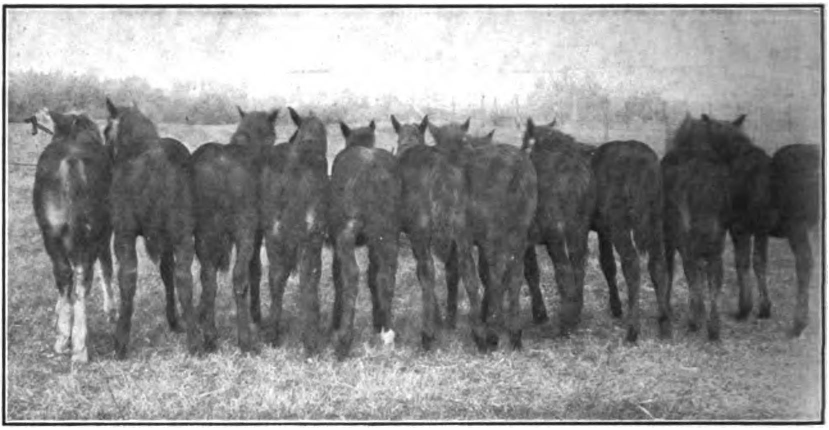

Fig. II. Colts at beginning of feeding experiment (rear view).

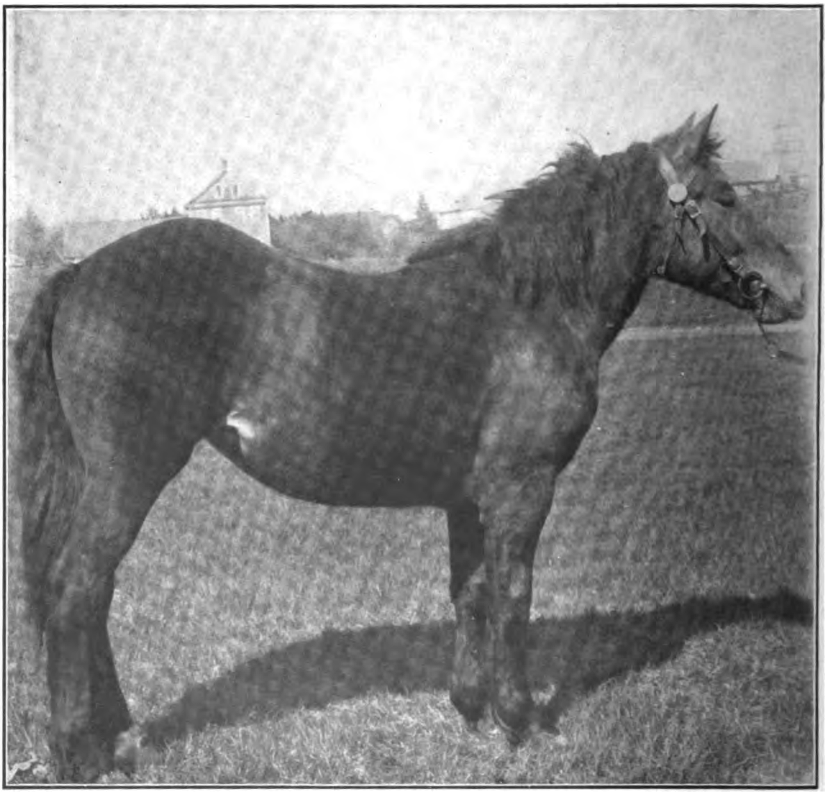

Fig. VI. Colt No. 30. A typical grade Belgian filly, foaled June, 1910. Weight, April 19, 1912, 1315 pounds. This filly made the largest gains of any in the group. Note the depth of middle and the large, wide, clean cannons, so essential in the modern draft horse.

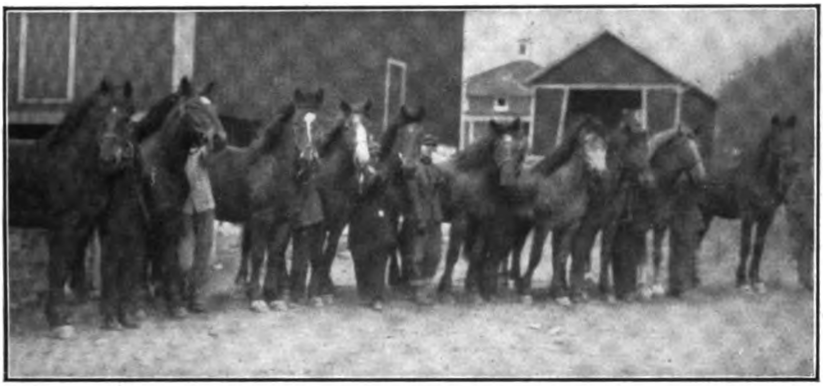

Fig. III. Colts at close of experiment (front view).

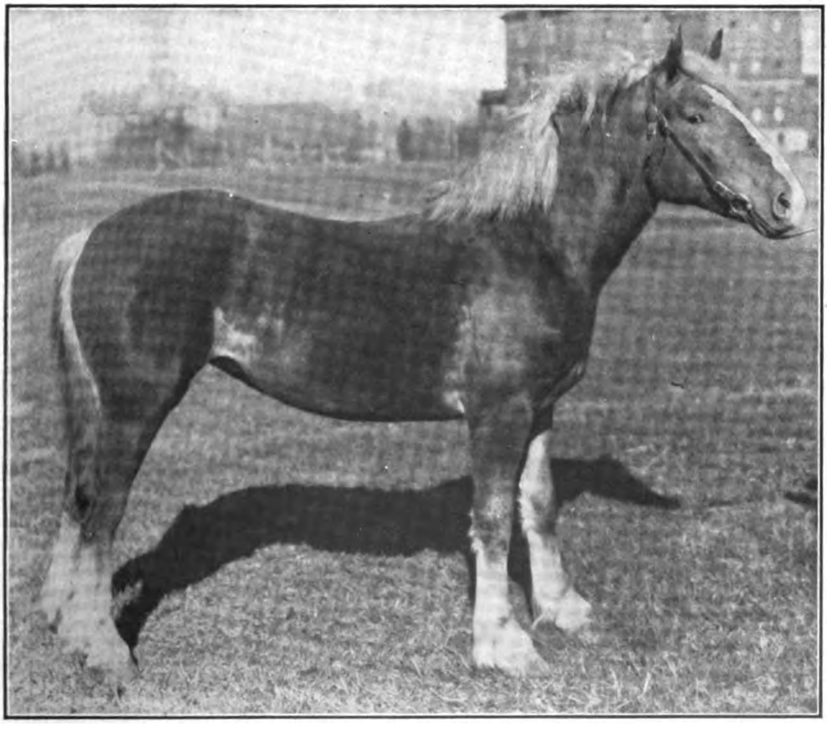

Fig. VII. Colt No. 22. Grade Belgian, foaled May 5, 1910. Weight April 19, 1912, 1311 pounds. A little more leggy than the typical Belgian due to Clydesdale foundation. This filly has the best style and action of any in the group.

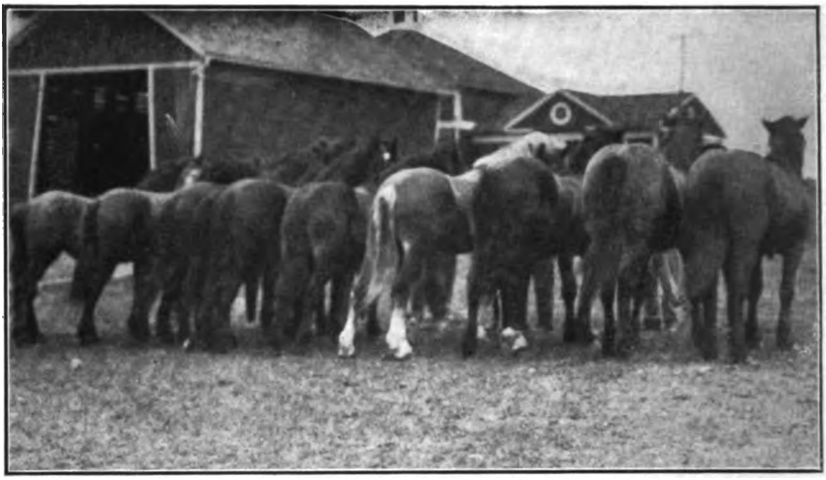

Fig. IV. Colts at close of experiment (rear view).

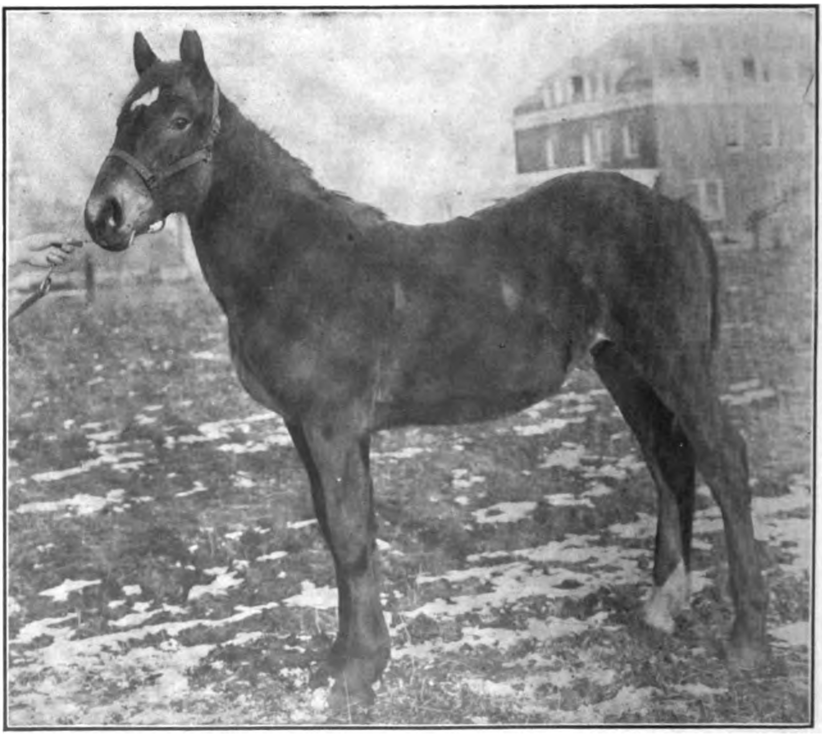

Fig. VIII. Colt No. 32. Pure Bred Percheron stallion colt. Foaled May 12, 1910. Weight Jan. 26, 1911, 713.3 Pounds.

From July 13 to 18, the fillies received no grain and the stallions were fed corn, as oats were not available. On September 7 and until the close of the summer feeding period, corn and oats were fed in equal parts by weight, each colt consuming eight pounds per head daily.

The total cost of feeding during the summer period was $27.45 per colt. This amount is twice as much as necessary where good and sufficient pastures are available. The four stallion colts consumed practically no grass and their maintenance and growth were derived from the grain and hay provided for them. The six fillies had a heavier supplement of grain than colts would consume ordinarily when placed on good pasture. For the development of draft horses, it is desirable to have them receive the greatest possible growth and development when less than two years old. Therefore, draft colts on pasture should receive as much grain as they will

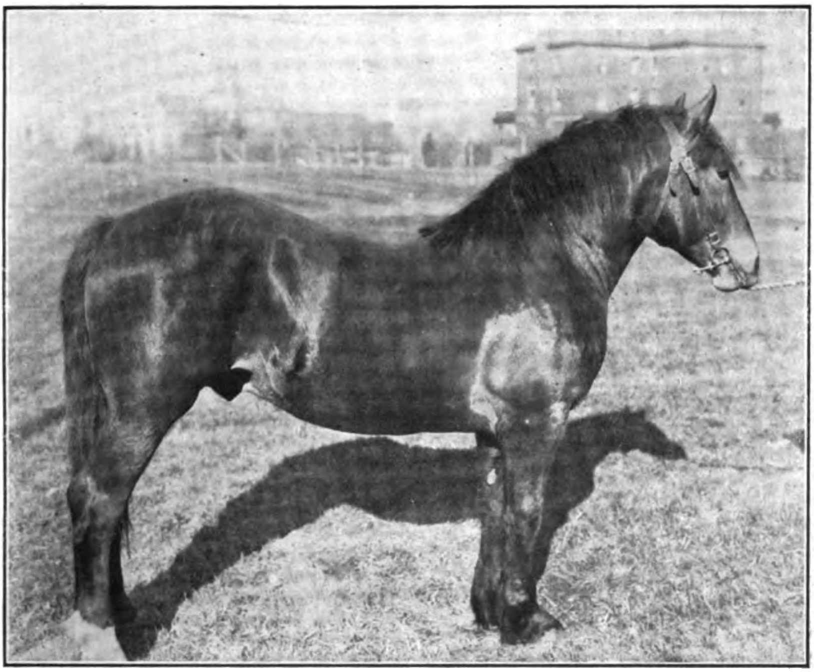

Fig. IX. Same as Fig. III. Weight April 19, 1912, 1350 pounds. Notice the change in development in head and neck due to sexual maturity, as well as the general improvement in form due to feed, care and management.

consume. With better pasture their appetites for grain are very materially lessened; therefore, in raising draft horses, one factor of reducing the cost is a sufficient amount of luxuriant pasture.

Second Winter, November 2, 1911—April 18, 1912.

As new corn was not available until December 1, the grain ration during November was largely oats, after which a grain mixture of six parts of shelled corn, two parts of oats, one part of wheat bran, one part of linseed meal, was used throughout the remainder of the test. During the first half of the winter, grain was fed at the rate of 8.4 pounds per head daily, after which it was increased to 10 pounds (where it remained stationary) until the close of the test. The hay fed during the same period amounted to 16.6 pounds

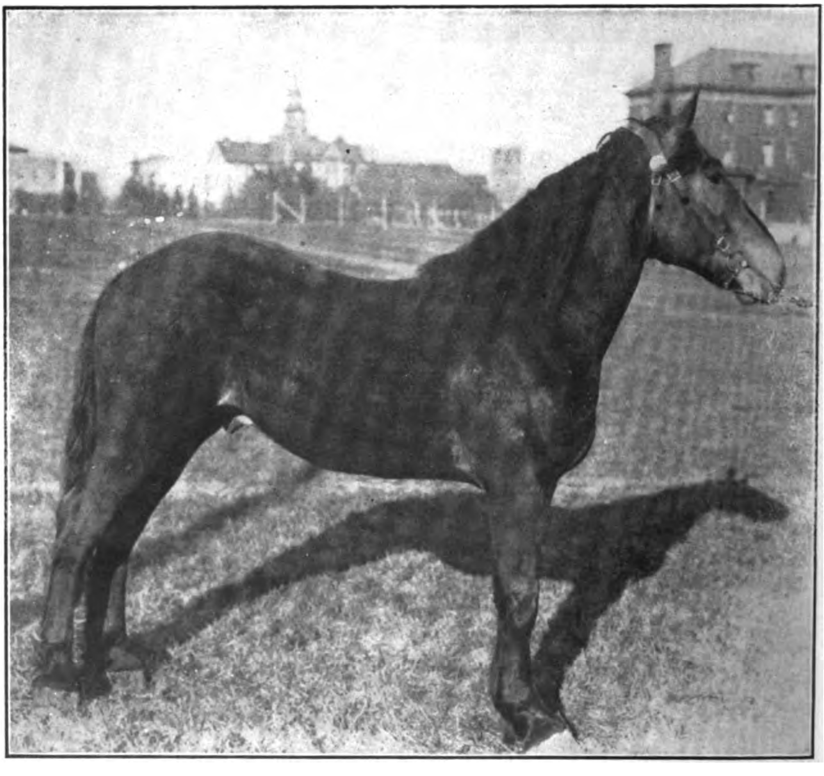

Fig. X. Colt No. 27, Grade Percheron, foaled May 5, 1910. Weight April 19, 1912, 1281 pounds. A type that does not mature until 6 years of age. Note the short back and exceptional quality in feet and legs.

and 17.5 pounds, respectively. The colts increased 219.25 pounds in weight during the second winter, and the weight at the close of the test, when approximately 23 months of age, was 1316.9 pounds per head. During the second winter, all colts were tied in single stalls. Because of ice and snow in the small exercise lots, it was thought that the risk assumed in turning them out would be greater than that of keeping them tied. They remained in good health and spirits throughout the entire winter and were broken to harness during the early spring months.

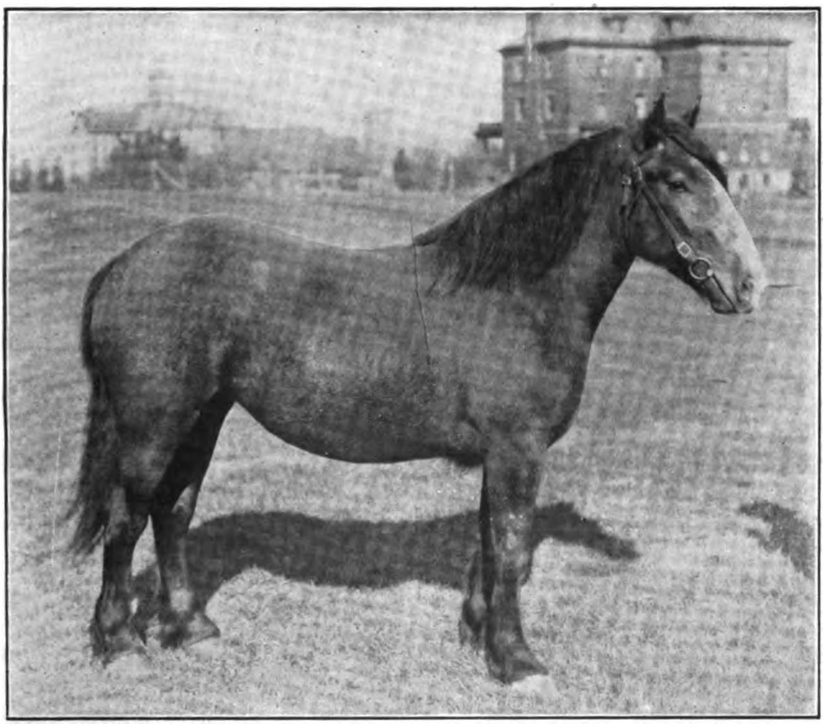

Fig. XI. Colt No. 23. Grade Percheron. Foaled April 20, 1910. Weight April 19, 1912, 1321 pounds. An extremely deep bodied, short legged and powerful type. This type matures at an early age.

Table I is presented in order to show the amount of feed consumed during different periods. It will be noticed that an increase of 60 per cent. in grain and 45 per cent. in roughage was consumed the second winter over that consumed during the first winter, although there was a decrease of 10 per cent. in the increase in weight, as shown in Table III.

Table I.—Showing Feed Consumed.

DATE	No. of Colts	Grain Mixture	Shelled Corn	Oats	Hay	Corn Silage
First Winter Period, 168 days:						
Nov. 3, 1910—Jan. 16, 1911..	4	1715 lbs	....	....	2488 lbs	2772 lbs
Nov. 3, 1910—Jan. 16, 1911..	6	2520 "	....	....	5363 "	.....
Jan. 26, 1911—Apr. 19, 1911..	10	5484 "	....	....	11030 "	.....
Total Winter Period, 168 days.	10	9716 lbs	....	....	18881 lbs	2772 lbs
Summer Period, 196 days:						
April 19—May 17, 1911.......	10	1292 lbs	20 lbs	231 lbs	3098 lbs	
May 17—June 14, 1911.......	10	305 "	....	1396 "	527 "	Pasture
June 14—July 12, 1911.......	10	....	....	1548 "	705 "	"
July 12—Aug. 9, 1911.......	10	....	196 "	1254 "	1073 "	"
Aug. 9—Sept. 6, 1911.......	10	....	....	2030 "	1536 "	"
Sept. 6—Oct. 4, 1911.......	10	....	1120 "	1120 "	2068 "	"
Oct. 4—Nov. 2, 1911.......	10	....	1280 "	1360 "	2808 "	"
Total Summer Period, 196 days	10	1597 lbs	2616 lbs	8939 lbs	11815 lbs	Pasture
Second Winter Period, 168 days						
Nov. 2, 1911—Jan. 24, 1912...	10	4810 lbs	264 lbs	2016 lbs	14011 lbs	
Jan. 24, 1912—Apr. 19, 1912...	10	8450 "	...	....	14713 "	
Total Winter Period..........	10	13270 lbs	264 lbs	2016 lbs	28724 lbs	

The cost of feeding each individual during the first winter was $26.59, during the second, $38.99, an increase of $12.40 per head. The average cost of feed per head for the first year after weaning was $53.97. These figures are based upon the average value of feeds for the period during which the test was in progress and are materially higher than the average of the past ten years. The method of feeding resulted in the use of slightly more than one and one-half times as much grain as roughage.

Table II shows the weight of each individual at the beginning and close of the test, also at the beginning and end of the summer periods. The average gain during the 532 days was 720.09 pounds per head. No effort was made to secure extreme weight, but the colts were kept in good growing condition. The smallest individual gain was 665.9 pounds by Colt No. 23; the largest 806.2 by Colt No. 30. The average daily gain gradually decreased as the age of the colts advanced and as they approached maturity. It is important in the development of draft horses that they progress steadily from birth to maturity without any period of semi-starvation, either during summer or winter, which indicates the necessity of varying the amount of grain as the available supply of roughage and pasture is either increased or decreased.

Table II.—Showing Weights of Colts at the Initial Weighing, the end of First Winter Feeding Period, the end of Summer Feeding Period, and the end of the Second Winter Feeding Period.

No. of Colt	Average Initial Weight Nov. 2, 3 and 4 1910	Weight at End of First Winter Period, Apr. 19, 20 and 21, 1911 168 days	Weight at End of Summer Period Nov. 1, 2 and 3 1911 196 days	Weight at End of Second Winter Period, Apr. 17, 18 and 19, 1912 168 days
	Lbs.	Lbs.	Lbs.	Lbs.
22	639.1	851.6	1132.3	1311.0
23	674.1	913.3	1137.3	1340.0
24	705.8	983.3	1129.0	1401.6
25	594.1	810.0	1094.3	1338.6
27	571.6	855.0	1120.0	1281.6
28	515.0	718.3	997.6	1231.3
29	584.1	855.0	1148.3	1375.6
30	509.1	800.0	1115.0	1315.3
31	478.3	678.3	988.3	1215.0
32	627.5	876.6	1115.0	1350.6
Total weight	5898.7	8341.4	10977.1	13169.6
Average weight per colt	589.87	834.14	1097.71	1316.96
Average gain per colt	....	244.27	263.57	219.25
Average daily gain per colt	....	1.45	1.34	1.30

Total gain per colt, 727.09 lbs. Average daily gain, 1.36 lbs

Table III.—Summary.

Nov. 3,1910—April 18, 1912

Initial value of colts	$912.50
Initial weight of colts	589.87 lbs.
Final weight of colts	1316.96 "

Cost of feeds:

Shelled corn	15985 pounds	@	60c. per bushel,	$171.199
Oats	16694 "	"	40c. "	209.675
Wheat bran	3383 "	"	$28. per ton,	47.362
Linseed meal	2355 "	"	36. " "	42.390
Silage	2772 "	"	3. " "	3.927
Hay	59420 "	"	14. " "	415.940
Pasture	10 acres	"	4. per acre,	40.000

Cost of labor—336 hours @ 15c. per hour, $50.400

Total cost of feed and labor	$ 980.893
Total cost of ten colts at close of experiment	1893.390
Value of ten colts at close of experiment	2350.000
Total profit on ten colts	456.610
Profit per colt	45.661

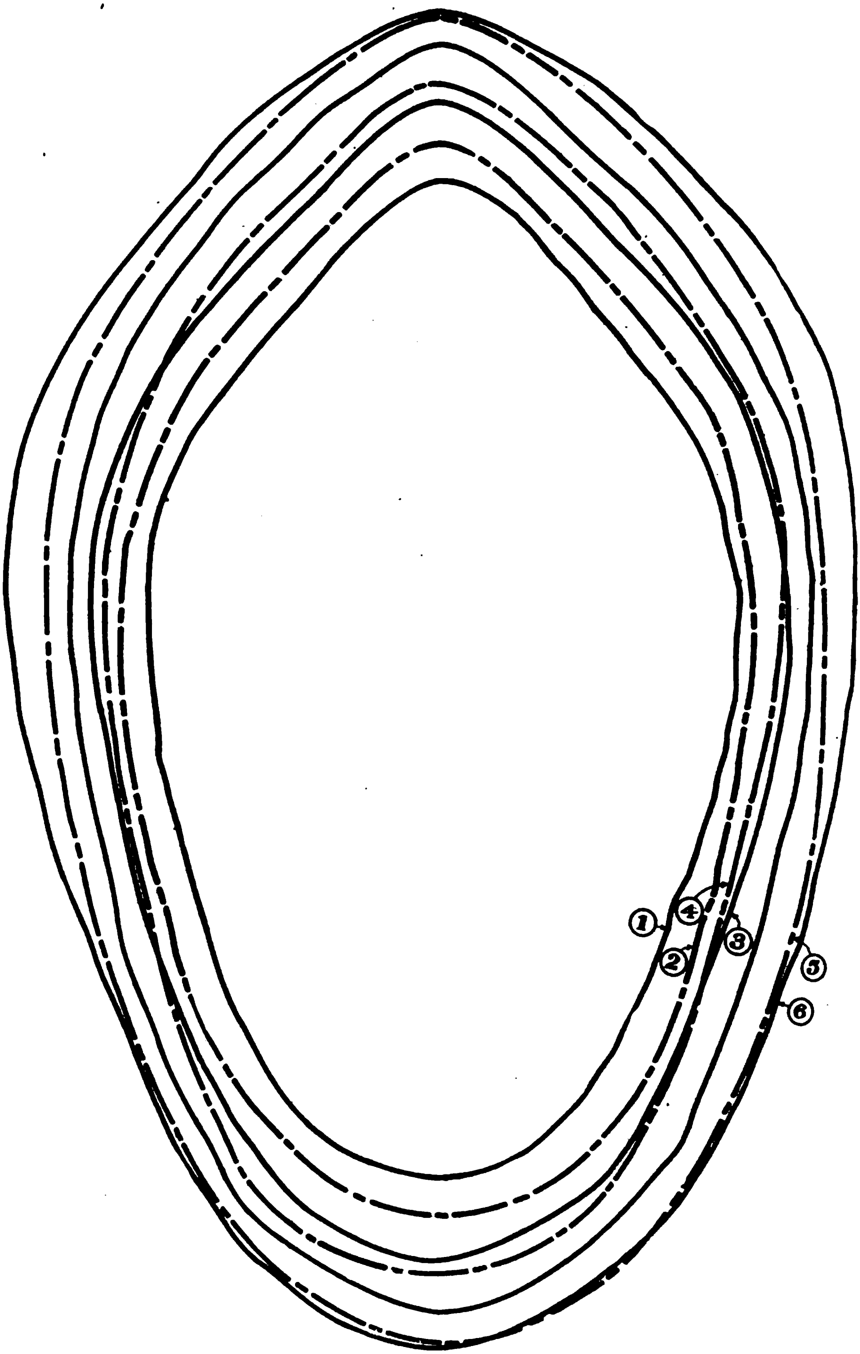

Chart I

Showing average outline of chest for ten draft colts at beginning of experiment and for intervals of three months thereafter until they reached a serviceable age.

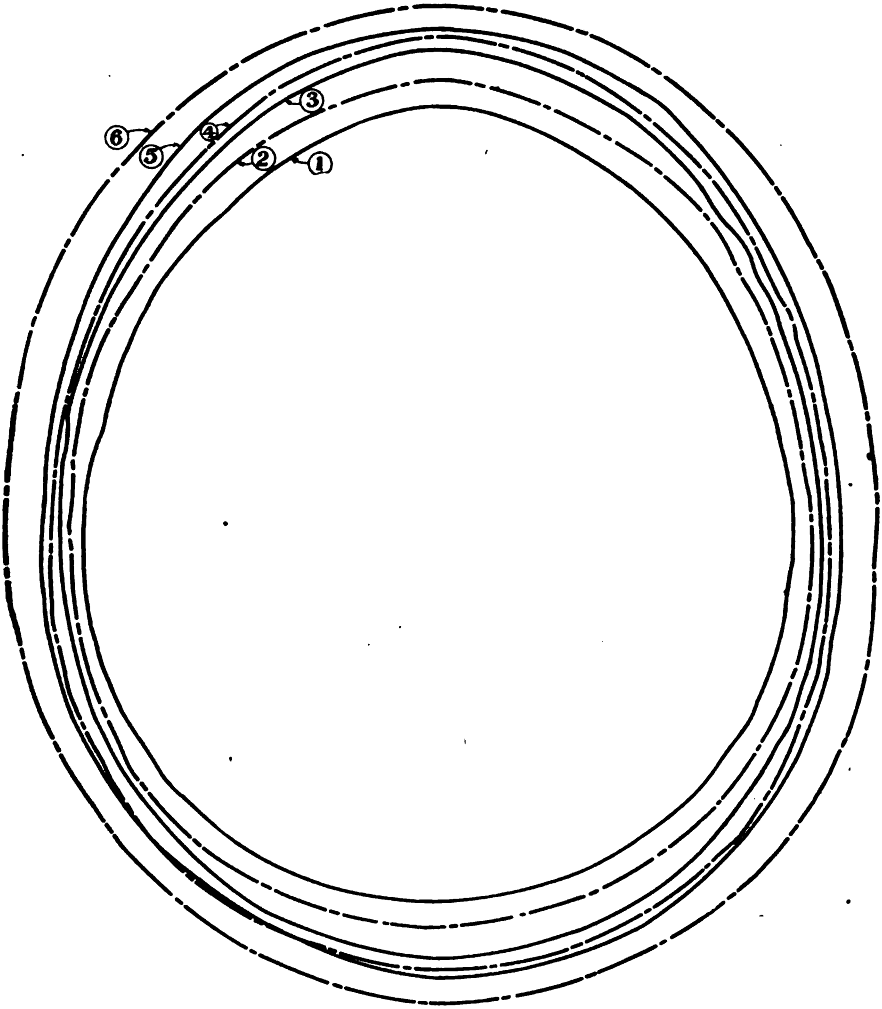

Chart II

Showing average outline at middle of paunch for ten draft colts at beginning of experiment and for intervals of three months thereafter until they reached a serviceable age

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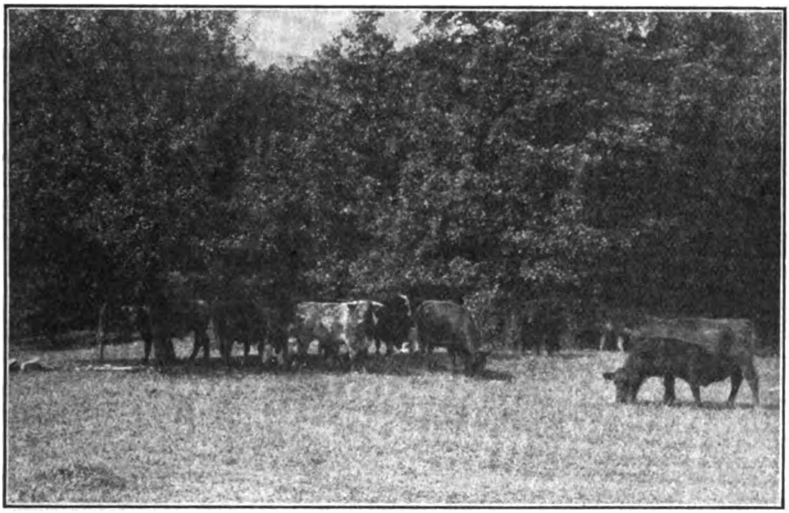
The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 123



TUBERCULOSIS

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
AUGUST, 1913.

AGRICULTURAL EXPERIMENT STATION
THE PENNSYLVANIA STATE COLLEGE

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 123

THE HISTORY OF TUBERCULOSIS IN THE COLLEGE HERD

BY H. H. HAVNER

SUMMARY

The conditions which should be borne in mind to prevent the entrance and spread, and to control the highly contagious nature, of tuberculosis, are:

1. The use of open sheds for confinement of breeding cows and young stock, and well-lighted, well-ventilated barns for dairy cows. ....Pages 11-12, 14
2. The feeding of healthy, nutritious and wholesome food at all times..Page 14
3. The prompt attention to all body disorders, especially the diseases of the respiratory system........................Pages 14-15
4. The avoidance of the breeding of animals of such conformation as would predispose to constitutional weakness...............Page 15
5. The pasteurization of skim milk, buttermilk, or whey before it is fed to young calves................................Pages 16-17
6. The use of strict precautionary measures in the purchasing of animals..Pages 15-16
7. The application of the tuberculin test and the isolation of all reactors and any emaciated or unthrifty individuals..........Page 17
8. The proper disinfection of the barn in which tubercular animals have been confined.............................Pages 18-20

Tuberculosis follows quite closely an intensified system of farming. The dairy sections of the country naturally suffer more than the sections in which beef cattle are produced. Although conditions have been improved in this state during the past few years, the disease is still quite prevalent in certain districts. According to figures given out by the Live Stock Sanitary Board for Pennsylvania, 8,902 herds containing 120,309 cattle have been tested for tuberculosis during the past sixteen years. Out of this number 18,359 were found to be diseased. The average percentage of reactors during this time was 15.2%. The records further show that the percentage of animals reacting has decreased gradually during the last three years. In 1909, the average percentage of reactors was 14.4%, in 1910, 13.6%, and in 1911, 11.3%. The fact that the percentage is decreasing should encourage the live stock breeders of the state to put forth more strenuous efforts in combating and suppressing the disease.

The history of tuberculosis in the College herd dates from 1892, at which time all of the mature cattle on the College farm were tested and found free from the disease. No test was applied after that date until 1906. From 1906 until the present time the College herd has been tested annually and a record kept as to the number of reactors for each year.

*1906.—Twenty reactors.** "In March, 1906, a test under the direction of the state veterinarian resulted in the condemnation and slaughter of fifteen animals."

In a second test applied in September, five animals were condemned, thus making a total of twenty reactors. During the intervening time between 1892 and 1906, a bull was purchased subject to the tuberculin test and placed at the head of the College herd. There is no other history as to the entrance of tuberculosis with the exception that in 1912 some of the heifers and one cow were pastured in the mountains during the summer with strange cattle.

1907.—One reactor. "A test made on mature animals in the month of January found the herd free from disease. A test on the yearlings and calves in March resulted in the condemnation of one calf." No animals had been purchased during this year.

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*History of 1906-09 taken from Reports of The Pennsylvania State College.

1908.—Four reactors. These were calves. All of the mature animals passed. No additional animals were purchased.

1909.—No reactors. "A test made June 2-5 found the college herd free from tuberculosis." No animals purchased.

1910—Five reactors. Five animals were condemned as tubercular on test made May 27, 1910. During this year 15 animals were purchased subject to the tuberculin test and placed in the College herd. Three of these newly purchased animals were reactors in the spring test of 1910.

1911—Twelve reactors. Three of these reactors were condemned in the test made upon the beef cattle herd on Dec. 12, 1911, and five cows and four calves were condemned in the dairy herd. In this year, 35 animals were added to the beef cattle herd and four animals to the dairy herd.

1912.—Thirteen reactors. There was one reaction from the beef cattle herd and twelve from the dairy herd. Two of the cows reacting had been purchased during the year subject to the tuberculin test and placed in the dairy herd.

Following each test the reactors were at once removed and placed in quarantine away from all other animals or else they were immediately slaughtered under inspection. Also, the barns were thoroughly disinfected following each test.

Report of Reactors in Quarantine

On May 27, 1910, Dr. E. P. Althouse was detailed by the Live Stock Sanitary Board to subject the College herd of beef and dairy cattle to the tuberculin test. For four years prior to the above date the College herd had been tested annually and the last test in 1909 showed the herd to be free from tuberculosis. During the latter part of 1909, some animals were purchased outside of the state subject to tuberculin test and placed in the College herd. On the test made on May 27, 1910, five animals reacted as follows:

(1) "The Exception" (Roan Shorthorn Bull). Calved May 26, 1909. Tested and passed as free from tuberculosis on Dec. 6 and 7, 1909. This bull was kept in the College barn from date of purchase until date of reaction, when he was given State Ear Tag No. 12736. His reaction was typical.

(2) Grover's Lassie (College Herd No. 2). Calved Jan. 12, 1908. Tested and passed on Nov. 22 and 23, 1909. This heifer was

kept on the ground floor in the wing of the College barn until date of reaction. She was given Ear Tag No. 12734.

(3) Queen Marshall (College Herd No. 5). Calved Feb. 12, 1908. Tested and passed Nov. 22 and 23, 1909. This heifer was kept in the same stall as Grover's Lassie. She was given State Ear Tag, No. 12735. Her reaction was not quite typical, the first temperature of the morning being normal, the second showing a rise of 2.8° and the succeeding temperature being normal.

(4) Grade Guernsey Cow (Herd No. 300). This cow was tested in 1908-09 and passed as free from tuberculosis at that time. For three years previous to her reaction she had been kept in the basement of the Experiment Station barn. Although there had been no new animals brought into the barn and she had passed the tuberculin test in the two preceding years, she showed a typical reaction. She was given State Quarantine Ear Tag No. 19246.

(5) Grade Guernsey Heifer (No. 427), was kept in open lot at the Thompson Farm in a herd of 40 young heifers which had been tested the preceding year and passed. No other animals had been added to this herd since the former test. This heifer was not so large as the others of the same age and breeding, though apparently thrifty. Her test was not quite typical, the temperature never reaching 3° above normal, but on account of her appearance it was thought best to consider her diseased. She was given State Quarantine Tag No. 12737.

As the three animals,—"The Exception," Grover's Lassie and Queen Marshall,—were valuable for breeding purposes, it was thought advisable to establish a quarantine lot so that the cows could produce their offspring and the bull could be used for service. The general plan of management of the five reacting animals was to keep them out of doors throughout the year, allowing them access to an open shed during the winter. Also each animal was to be tested twice annually in order that a record might be kept of the progress of the disease. The calves were to be allowed to run with their dams until six months of age, when they were to be subjected to the test. If they proved to be free from the disease, they were to be transferred to the College herd at that time. The pasture in which these animals were kept was situated so that no other cattle could come within 100 feet of the reactors. They were watered from troughs used by no other cattle and the isolation was made as complete as possible.

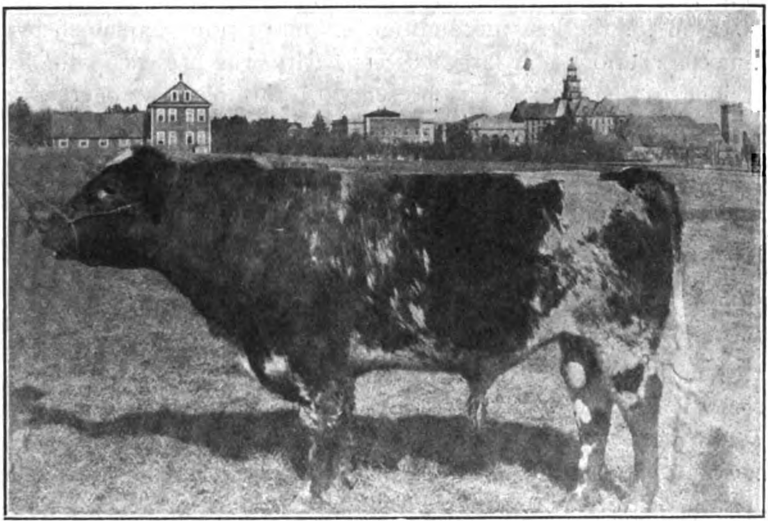
The following record of the quarantine herd was kept:

1. General health and condition of each individual from time of quarantine until disposal.

2. Behavior when subjected to the tuberculin test semi-annually.

3. Transmission of disease to healthy animals under open air conditions.

4. Post-mortem findings.



SHORTHORN BULL.

Although showing no outward symptoms of disease, this bull reacted to three tuberculin tests and confirmed the diagnosis of tuberculosis by showing the post-mortem lesions of the disease.

Health of Animals While in Quarantine Lot

With the exception of the aged Guernsey cow (No. 300), all of the animals remained in an apparently healthy condition while the experiment was in progress. Observations indicated that the animals laid on flesh and were in higher condition at the close of the experiment than at the beginning. The gain and increase in body fat was as satisfactory as could be expected with normal healthy individuals. The ration fed consisted of pasture grass exclusively during the months of May, June, July, August and September and of mixed hay and a small amount of ear corn during the fall and winter months. The two Shorthorn cows,—Grover's Lassie and Queen Marshall.—

when sold on the open market at Harrisburg on Jan. 3, 1912, made a combined dressed weight of 1185.5 pounds which sold at $8.77 per hundred, thus returning $103.73 as beef. The Guernsey heifer (No. 427) was killed in the slaughter room of the Agricultural Building and when dressed showed a fairly large and uniform deposit of fat over the carcass.

From the picture of the Shorthorn bull, it can be seen that from a physical standpoint he is entirely healthy and furthermore is in very good condition for a breeding animal.

Guernsey Cow No. 300 lost in flesh while in the quarantine lot. The reason for the loss in condition is quite readily explained by the post-mortem lesions. A large abscess cavity was present in the lower right lobe of the liver. The presence of this abscess together with extensive involvement of the mesenteric lymph glands proved to be too strong an affection for the body to hold in check.

Behavior When Subjected to the Tuberculin Test Semi-Annually

The first test made upon the reactors after being placed in the quarantine lot was applied on Oct. 21 and 22, 1910. The animals were tied to the fence in an open lot during the entire test. There was some difficulty in haltering the animals before the first temperature reading was taken, consequently there was a slight rise above normal temperature in the first preliminary reading. They were exposed for a few hours during the early morning of the 22d to a moderate downpour of rain which was accompanied by a considerable drop in atmospheric temperature. They were watered from bucket at 12:30 P. M. on second day of the test (Oct. 22). Each animal was injected with 1 dram Retest Tuberculin at 10:20 P. M. Oct. 21. From the temperature readings it will be noted that there was not over 1° rise in post-injection temperature in any case. Thus a typical reaction was not shown in any one of the five animals.

Temperature readings were as follows:

Table I.

	OCTOBER 21, 1910				OCTOBER 22, 1910				
	2.30 P. M.	5.00 P. M.	7.30 P. M.	10.00 P. M.	6.30 A. M.	8.40 A. M.	10.30 P. M.	12.15 P. M.	3.00 P. M.
"The Exception"	103.2	102.3	102.4	102.5	102.0	101.0	100.4	100.4	100.5
Grover's Lassie..	103.4	102.1	101.7	101.4	102.0	102.0	101.7	101.6	101.7
Queen Marshall..	102.6	101.9	102.4	101.9	102.7	102.4	102.8	103.0	103.1
Guernsey No. 300	102.8	101.7	102.3	103.6	101.7	101.1	102.0	102.0	101.3
Guernsey No. 427	102.5	102.1	102.2	102.4	101.2	101.2	101.5	101.4	100.7

The second retest was made on Sept. 5 and 6, 1911.

All of the necessary precautions in regard to handling, confinement and watering were observed in detail. The animals were watered before 1:30 temperature on Sept. 5, and after 8 o'clock temperature on Sept. 6. Each animal was injected with 1 dram retest tuberculin at 10:00 P. M., Sept. 5.

Following are the Pre-Injection and Post-Injection Temperatures:

Table II.

	Pre-Injection Temperature			Post-Injection Temperature				
	1.30 P. M.	4.00 P. M.	9.00 P. M.	6.00 A. M.	8.00 A. M.	10.00 A. M.	12.00 M.	2.00 P. M.
"The Exception"......	101.9	101.9	103.0	101.4	102.5	103.0	103.6	103.8
Grover's Lassie........	101.0	101.4	101.9	101.0	101.9	104.0	103.2	102.3
Queen Marshall	101.0	101.2	102.1	100.9	101.3	101.4	101.2	101.0
Guernsey No. 300	100.9	101.2	101.9	101.2	101.7	102.2	....	......
Guernsey No. 427	101.2	101.8	101.8	101.0	101.8	101.8	101.8	101.3

All passed a very satisfactory test, as indicated by temperature readings, with the exception of Grover's Lassie, No. 2. This animal showed a rise of 2.1 from maximum pre-injection to maximum post-injection temperature readings. Following this test, Guernsey cow, No. 300, was slaughtered, and on Dec. 6, Guernsey heifer, No. 427, was also destroyed. (Post-mortem finding on page 13). This left the Shorthorn bull, two Shorthorn cows and Guernsey bull calf in the quarantine lot. The last named animal had been put in lot to take milk from one of the cows.

The next retest was made on Dec. 23, 1911.

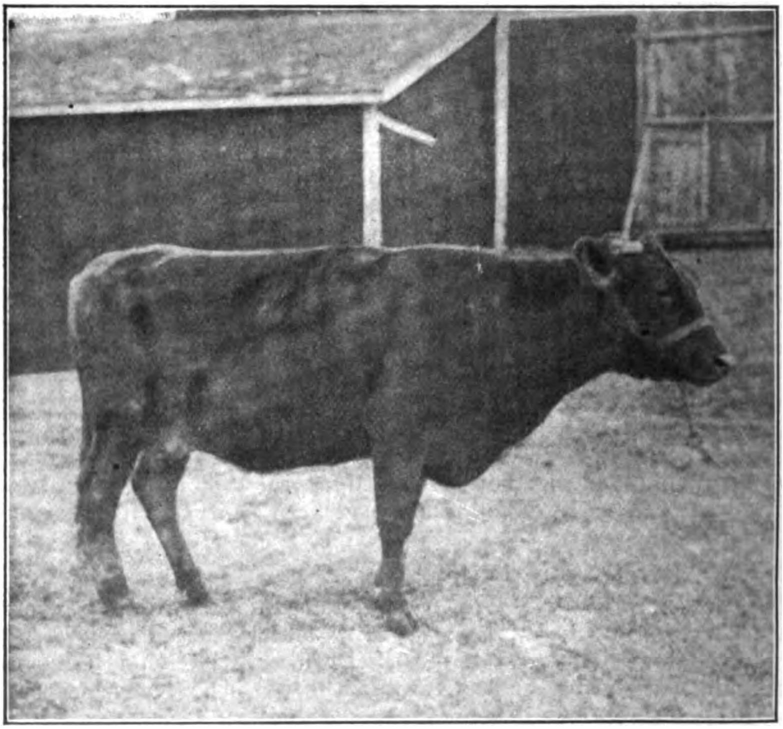
"The Exception" and Grover's Lassie No. 2, each showed a typical reaction. Shorthorn cow, No. 5, showed a marked change in post-injection readings. The test of the Guernsey bull calf put in the lot to take milk from one of the beef cows is included in this table.

Table III.

	Pre-Injection		Dose o Tuberculin	Post-Injection			
	5.00 P. M.	9.00 P. M.		6.00 A. M.	8.00 A. M.	10.00 A. M.	12.00 M.
Shorthorn Bull—							
"The Exception"......	101.6	101.4	1 dram	101.5	103.0	104.8	104.8
Guernsey Bull Calf.......	101.8	101.7	3 c.c.	101.0	101.4	101.1	101.4
	4.00 P. M.	11.00 P. M.		7.00 A. M.	9.00 A. M.	11.00 A. M.	
Shorthorn Cow No. 2....	101.9	101.6	1 dram	102.0	102.6	104.5	
Shorthorn Cow No. 5....	101.7	103.0	"	101.7	101.4	101.6	

From the above information, it is noted that no one of the five animals in quarantine showed a reaction in the first retest as shown in Table I, made on Oct. 21 and 22, 1910. On the retest of Sept. 5 and 6, 1911 (Table II.), Grover's Lassie showed a reaction, although not entirely typical.

On the retest of December 23, (Table III) Grover's Lassie gave a rise of 2.8 degrees and "The Exception" a rise of 3.2 degrees between highest pre-injection and highest post-injection temperatures. Shorthorn cow No. 5, did not show a reaction in any of the retests. Guernsey cow No. 300, and Guernsey heifer No. 427, showed no material rise in temperature after injection of tuberculin on the retests of Oct. 21, 1910, and Sept. 5, 1911.

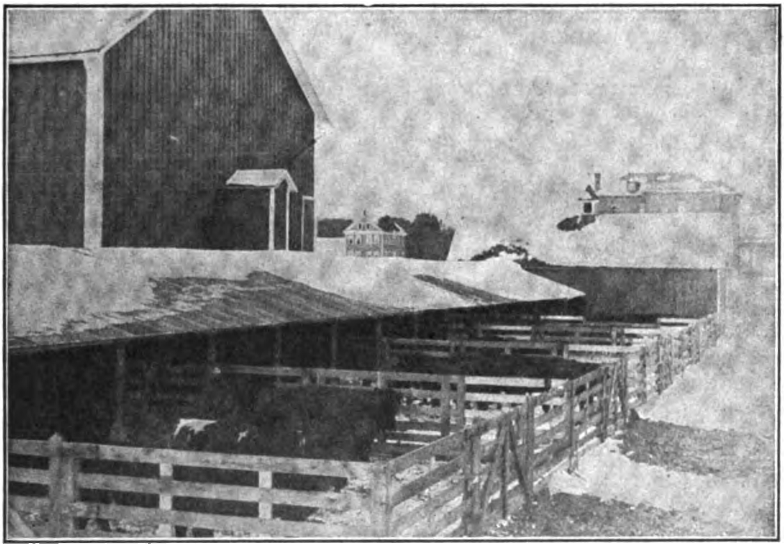


SYBIL, AGE 10 YEARS.

Suspicious to the test of December 23, 1911. Placed in quarantine and retested in March, 1912. She showed a typical reaction on the last test and when slaughtered in April was found to be diseased.

Transmission of Disease to Healthy Animals Under Open Air Conditions

During the time the reactors were in quarantine, there were six healthy calves put in the quarantine lot at different times and allowed to remain for periods varying from five weeks to three months. These animals were slaughtered and examined on post-mortem immediately after they were removed from lot. No trace of tuberculosis was found in the six carcasses. It must be remembered, however, that we do not know that the reacting cows were excreting tubercle bacilli through the milk, as a bacteriological examination was not made. The milk very likely was free from germs of the disease, as none of the diseased cows showed tuberculosis of the udder on post-mortem examination. The calves had that chance, however, of becoming infected through soiled teats or by breathing in the germs, provided the tubercle bacilli were being excreted through the feces and respiratory tract. In two individual reactors it was known quite positively that they were secreting bacilli through these two channels.



OPEN SHEDS FOR WINTERING BEEF BREEDING COWS.

The cows which were wintered in these sheds and pastured in the open in summer passed two tuberculin tests without a single reaction.

It should not be inferred, because these calves did not contract tuberculosis when kept with diseased cows under open air conditions, that it would be advisable to allow calves to suckle cows that were diseased. In this case, the animals were out of doors continually, and the information pertaining to the transmissibility of disease to healthy animals under open air conditions is cited only to show that tuberculosis is a disease principally of stabled cattle and is not of dangerous character in cattle kept in the open air. Tuberculosis is practically unknown to the western ranchmen whose cattle are stabled only in a pure atmosphere. In this connection, it can be stated that in the tuberculin tests made at the College during the last two years there has never been a single reaction in the beef cattle breeding cows that were wintered in open sheds and pastured entirely in the open during the summer. Only one suspicious case was found in that portion of the dairy herd which was confined and pastured in a similar manner.

During the past seven years at this College, experiments in feeding steers in open sheds versus basement barn show conclusively that steers fed in the open sheds make more rapid gains, show more finish and return a larger profit. During the winter of 1911-12, 20 beef breeding cows were confined in the same open sheds in which the steers had been confined in previous years. From Dec. 1 until April 19, these 20 cows made a total gain of 3291 pounds or an average gain of 164.5 pounds, on a ration of 57 pounds of corn silage and 1 pound of cottonseed meal per head daily. They were on pasture the remaining months and passed two tuberculin tests without a single reaction. If beef cattle can be handled more profitably under open shed conditions, at the same time materially lessening the liability of the contraction and spread of tuberculosis, there seems to be no well-founded reason for close stabling of the beef cattle herd, thereby endangering the health of the individuals.

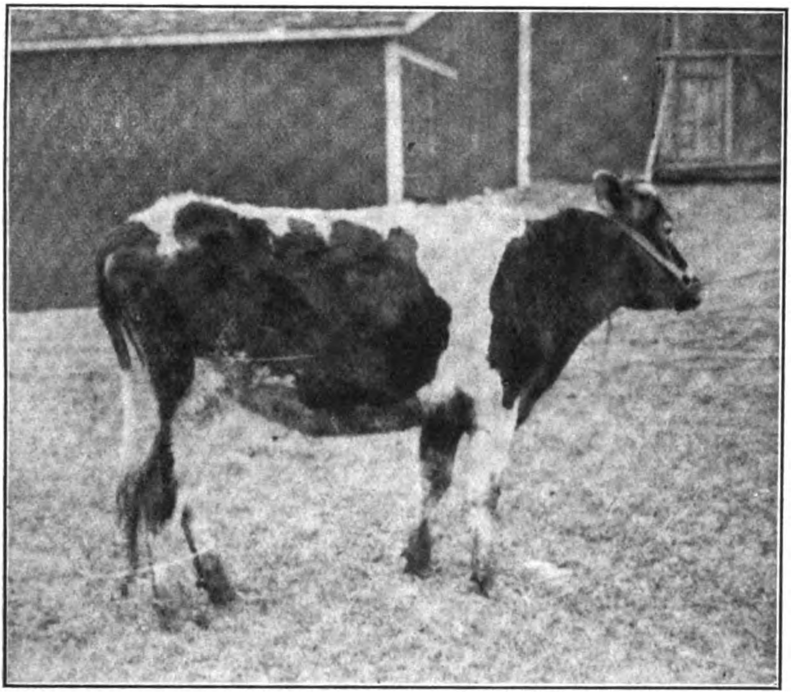
Post-Mortem Findings of Animals Kept in Quarantine Lot

"The Exception" (Roan Shorthorn Bull).—Quarantine Tag No. 12736. Caseo-calcareous nodules in mediastinal lymph glands. Carcass passed for food. Viscera condemned.

Grover's Lassie (Shorthorn Cow No. 2).—Quarantine Tag No. 12734. Extensive bronchial involvement, showing enlargement and caseation of lymph glands of chest cavity. Carcass passed for food. Viscera condemned.

Queen Marshall (Shorthorn Cow No. 5).—Quarantine Tag No. 12735. Unable to find nodular formations in lymph glands or on the liver, in lungs, intestines or generative organs. Brain and bones were not examined, owing to the fact that carcass was sold for beef. Carcass passed.

Grade Guernsey Cow No. 300.—Quarantine Tag No. 19246. Adhesion of spleen to diaphragm. Nodular formation in spleen; liver surrounded by abnormal fibrous capsule. Large abscess cavity filled with yellowish purulent material in lower part of right lobe of liver. Tissue of liver very hard and indurated, cutting like tough leather.



A HEIFER WITH ADVANCED SYMPTOMS OF TUBERCULOSIS.
An animal of this appearance would be suspicious in a physical examination.

Caseous formation in lymph glands draining liver and intestines. Carcass condemned.

Grade Guernsey Heifer No. 427.—Quarantine Tag No. 12737. Bronchial lymph glands enlarged to three or four times natural size. Also small caseous lesions in center. Lungs slightly discolored, borders showing whitish oblong elevations on surface. Other organs normal as far as observed. Carcass used in meat cutting demonstrations. Viscera condemned.

Some Important Factors Bearing Upon the Prevention and Suppression of Tuberculosis in Cattle

Light and Ventilation.—Sunlight is a powerful, destructive agent of tubercle bacilli. The most active of these organisms can only live a few hours in the direct rays of the sun. Sunlight costs absolutely nothing. All that is necessary is to place a sufficient number of windows in the barn to admit an abundance of light. In a barn in which there is no system of ventilation, the animals confined must depend upon the open doors and windows for their supply of air. These doors and windows will not admit enough fresh air for even one-third of the animals confined. When fresh air is not supplied, the atmosphere grows more impure with each breath, and the impurities are further increased by the decomposition of the organic material of the stable. Almost any individual will become unthrifty if confined in a dark, damp, close, foul-smelling stable even if proper feeds are given. Tuberculosis spreads with great rapidity in these poorly ventilated and badly lighted stables. The foul, humid atmosphere laden with impurities can be done away with by installing a system of ventilation with outlets and inlets in the form of shafts and windows.

Nutritious Feed.—One of the primary essentials in successful management of live stock is to maintain all individuals of the breeding herd in a healthy, vigorous condition. This is accomplished in the first place by feeding wholesome, nutritious feeds in proper combination. If a sufficient amount of the several food nutrients is not given to the milch cow for the production of milk, she will draw from her body for the food material that is lacking in order to keep the milk to its proper standard. An animal in a poor, unthrifty condition, due to an insufficient supply of proper food material, is more apt to contract tuberculosis, owing to her weakened condition. A strong, healthy, vigorous animal is able to withstand infection for a longer period of time.

Body Disorders.—Any body ailment of cattle, which throws the system into disorder, lessens the power of resistance of the body to tuberculosis. Especially do we find this to be the case with diseases of the respiratory tract. The diseased and deadened mucous membrane of the bronchi and lungs, which has been caused primarily by an attack of bronchitis or a slight attack of pneumonia, offers a favorable entrance for the tubercle bacilli. If this membrane is entirely healthy and not altered in structure, there would be less liability of the germ lodging and entering the animal body. Immediate attention should be given to the various body disorders, especially to the diseases of the respiratory tract. It should be the aim to avoid these diseases as far as possible by proper hygienic care and management and to attend to such cases immediately should any occur.

Constitutional Vigor.—A strong constitution is indicated by large nostrils, a broad, strong muzzle, a deep chest and a roomy middle. The wide muzzle and roomy middle are in direct relation to the feeding capacity of the individual. The ability to consume a large amount of feed is a condition which is sought for in both the dairy cow and beef animal. This is true because an increased consumption of feed in the case of a beef steer means an increase in daily gain. A dairy cow that is capable of consuming a large grain and roughage ration has a higher milk yield than a cow with a similar milk test, a similar disposition and udder development, but of inferior feedng capacity. Large nostrils indicate a large lung surface, and a deep chest indicates a large chest cavity with plenty of room for breathing. A cow with small nostrils and a shallow, pinched chest materially lacks in constitutional vigor. Breeding cows having this conformation will transmit the condition to their offspring, and a lack of constitutional vigor is one of the predisposing causes of tuberculosis.

Buying Tuberculosis.—In the improvement of cattle, it becomes necessary to add breeding cows or bulls from other leading herds of the same breed. By the purchase of these breeding cattle, an owner may bring in one or two badly infected individuals which are placed in the same stable with the breeding herd. The diseased cattle are fed by the same attendant, with the same utensils, watered from the same trough, and closely stabled with the healthy cattle, thus in a comparatively short time infecting the healthy cattle of the original herd. Prior to this time, the purchaser probably had very little trouble with tuberculosis, but six months or a year after the entrance of these animals, upon application of the tuberculin test, he finds a dozen or more reactors in his herd. This is the exact condition that occurred in the College herd. In the year 1909, upon application of the tuberculin test, the College herd was found to be free from tuberculosis. During the fall of 1909, quite a number of breeding animals were purchased outside of the state, subject to the tuberculin test, to be used in building up the College herd of beef cattle. When the tuberculin test was applied again in May, 1910, five animals reacted. Three of these were breeding stock that had been purchased in the fall of 1909, subject to the tuberculin test. The same trouble was experienced with the dairy herd. Following the purchase of animals during the spring and summer of 1911, nine animals reacted to the test which was made on Dec. 23, 1911. These newly purchased cows, as was the case with the beef cattle, had passed the test before shipment to the College. (This does not necessarily imply that the tuberculin test was not applied accurately, although such might have been the case). The fact that the animals passed a satisfactory test before shipment might have been due to inaccuracy in testing, to an advanced stage of tuberculosis not recognizable by test (but should have been by symptoms) or to the fact that the infection was so recent that no lesions were present and consequently the dose of tuberculin could cause no systemic reaction.

A REACTING HEIFER.

Note the harsh staring coat and unthrifty appearance.

Tuberculosis Through the Feeding of Skim Milk.—In connection with a dairy, calves are reared on skim milk, buttermilk or whey after the first week. If one or two cows in the herd are giving off tubercle bacilli in their milk or the milk is being contaminated by manure and dirt falling into the milk pail during the milking process, the skim milk which is used as a calf feed will contain the germs of tuberculosis. This milk is very likely then to be the means of spreading tuberculosis from the older cows to the young stock in the calf pen. The skim milk from creameries returned to the farm for feeding purposes is very likely to contain tubercle bacilli, as the milk is collected over a large territory and from a number of different farms. The transmission of tuberculosis through the feeding of skim milk to calves can be avoided by pasteurization. The heating of milk to 175 degrees F. for five minutes is sufficient to kill all of the bacilli present.

The Application of the Tuberculin Test

The purpose of the tuberculin test in cattle is to aid in recognizing those cases of tuberculosis which have not advanced far enough in course to be recognized by a physical examination; also to confirm a suspicious diagnosis as evinced by clinical symptoms. Tuberculin is absolutely harmless to a healthy individual, and affects a diseased animal only temporarily, acting as a specific irritant upon the tuberculous lesions, thereby causing an elevation in temperature, an increased number of respirations and an increase in number of heart beats. The test can be applied with perfect safety to a herd and with a certainty of diagnosing over 90% of the cases of tuberculosis, provided it is applied by a veterinarian who is familiar with all the details of testing. It must be remembered, however, that the tuberculin test does not indicate the extent or progress of the disease, but recognizes the affection even if only a small portion of the body is diseased.

In starting to clean up a herd, if quite a large number of reactors are found on the first test, it might be advisable to make another test in six months. If the number of reactors decrease in this test, it will probably not be necessary to test again for a year. When no reactors are found, it will only be necessary to test every two or three years, which will serve as a check to any accidental means of infection. Animals reacting to the test can either be slaughtered at once or separated from the healthy animals and placed in quarantine. If the cows reacting are valuable for breeding purposes, the latter plan would perhaps be the best method to follow. In this case, they could be kept in quarantine until the offspring is dropped, at which time the young calf should be taken from the lot and reared upon a healthy cow or fed upon pasteurized milk from the reactors. In this state, the Live Stock Sanitary Board has charge of all the testing as well as control of any animals which have been put in quarantine. This board is able to make tests at a moderate expense upon application of the owner.

Disinfection of Barn

In case a number of reactors are found, it is necessary thoroughly to disinfect the stable in order to kill all of the living germs which are present and thus prevent further infection of the healthy animals. In such a disease as tuberculosis, it is necessary to perform the disinfection as thoroughly as possible. This is true because the germs are very hard to destroy and can only be killed by the use of strong disinfectants. A very common method of disinfection of stables is given below. This plan is practical and thorough and should be followed in detail.

Plan of Disinfection

1. Remove all manure, litter, loose dirt, loose, rotten boards and scrape the floor clean.

2. Sweep the ceilings and walls free from cobwebs, dust and dirt.

3. Wash the feed boxes, mangers, stanchions and partitions with hot water containing enough lye or washing powder to cut the dirt. Scrub all of these objects vigorously with a stiff brush.

4. Spray the walls, ceilings and floors with bichloride of mercury solution (1-1000) or a 5% carbolic acid solution (not crude).

5. Flush the floors with a saturated solution of iron sulphate or a solution of chloride of lime (1 lb. to 3 gallons of water).

6. Spray interior of feed boxes, mangers, stanchions and partitions with the 5% solution of carbolic acid. This is done for the reason that there is danger of poisoning the animals if the bichloride of mercury is used for spray upon those structures which the animals can lick with their tongues. The carbolic acid is absolutely harmless if used in a 5% solution.

7. A whitewash applied to walls, ceilings and partitions will add to the cleanliness of the stable.

Mixing and Applying the Disinfectants

Carbolic Acid.—To make a 5% solution, use one part by weight of pure carbolic acid to twenty parts of water. Add the carbolic acid to a gallon of moderately warm water, stir vigorously, then add enough more warm water to make the desired amount. The solution can be applied with spray pumps, sprinkling cans or with a brush.

Bichloride of Mercury.—In the mixing and application of bichloride of mercury, it must be remembered that this disinfectant is extremely poisonous when taken internally, not only to cattle but also to man. The buckets, tubs, spray pumps and sprinkling cans which have been used in applying the solution should be thoroughly scrubbed with soap and rinsed with clean water before using for any other purpose. Bichloride of mercury will corrode metal, so that it is well to use wooden utensils. The mercury solution must be used with caution about the feed boxes, mangers and stanchions for fear of the cattle contracting mercuric poisoning by licking these objects. For this reason, it is advisable to use the carbolic acid on the feed boxes and mangers and the bichloride of mercury for the walls and ceilings. To make up the bichloride of mercury solution (1-1000) use one-eighth of an ounce of corrosive sublimate to a gallon of water or one-half ounce to four gallons. The addition of a small amount of sal ammoniac will cause the corrosive sublimate to dissolve more easily. It is advisable also first to add the corrosive sublimate to about one gallon of moderately warm water containing the sal ammoniac. Stir thoroughly and after all of the particles have been dissolved, add enough clear water to make the required amount.

Iron Sulphate (*Copperas*).—To make a saturated solution, as much iron sulphate should be dissolved in the water as possible. Put the copperas in a barrel or some solid container, pouring in water and allowing solution to stand for a day. The liquid above the sulphate of iron will be the saturated solution which is to be used on the floors and gutters.

Chloride of Lime.—This lime solution is used in the proportion of one pound of lime to three gallons of water. It is a very good disinfectant for floors, gutters and partitions and can be applied with brush, sprinkling can, pump or bucket.

Disinfection of Old Stables

It is hard to bring about a thorough disinfection in old, dilapidated stables with numerous openings in the floors, walls and ceilings and with rotten woodwork lining the interior. In stables of this description, the most thorough disinfection will miss some of the organisms. If a badly infected herd is found in an old wornout tottering stable, the most practical thing to do would be to vacate the structure entirely for a period of two years or to tear it down. It would be a waste of time, labor and money to make a thorough disinfection of these old structures.

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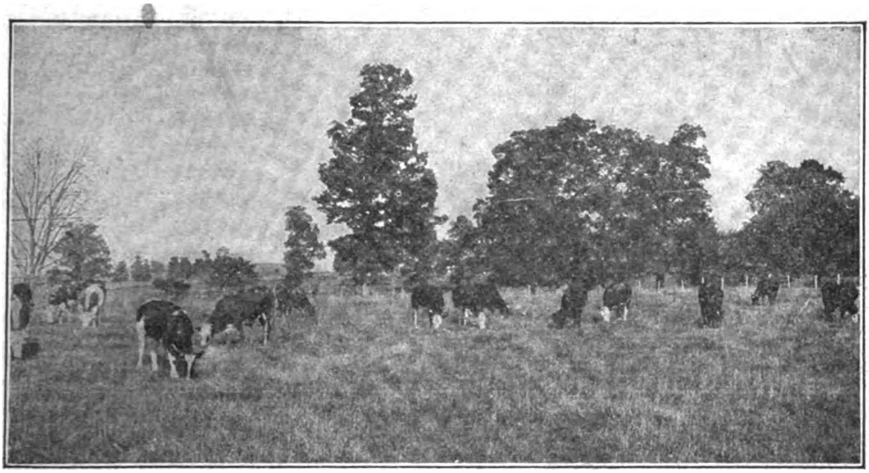
The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 124



STEERS ON PASTURE

STEER FEEDING EXPERIMENTS

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
SEPTEMBER, 1913.

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 124

STEER FEEDING EXPERIMENTS AT THE PENNSYLVANIA STATE COLLEGE

By W. H. TOMHAVE and B. O. SEVERSON

CONCLUSIONS.

1. Corn silage at $3.50 per ton is more economical as a sole roughage for feeding steers than a combination of silage and mixed hay when hay is valued at $12.00 per ton.

2. Corn silage was found more palatable for fattening steers than ear corn, which makes it necessary to limit the amount of silage in the ration in order to insure the greatest gain in flesh during the finishing period.

3. After paying farm prices for other feeds consumed (as indicated in Table VII), the steers in Lot I (silage as a sole roughage) returned $1.469 per bushel of corn. Lot II (silage and mixed hay as a sole roughage) returned $1.308 per bushel.

4. The margin necessary between the buying and selling prices in Lot I was .57 cents and in Lot II .71 cents per hundred pounds, live weight.

5. Steers returned $2.23 more per head for feed consumed when followed by hogs in the feed lot.

6. Net profits received from experimental feeding cattle under Pennsylvania conditions, not including pork produced, during the winter of 1912-1913 ranged from $11.224 per head for Lot II to $14.095 per head for Lot I.

INTRODUCTION.

The high prices received for beef cattle during the winter of 1911-1912 created considerable interest in beef cattle feeding in Pennsylvania. Feeding cattle were high in price in the fall of 1912 which kept many farmers from purchasing steers to feed. The large corn and hay crops all over the country reduced the prices received for these feeds as compared to the previous year and brought greater returns to the farmer who fed his crops to cattle than when these feeds were sold on the market. The scarcity of beef cattle had a tendency to hold up the value of cattle during the entire winter and spring, resulting in substantial profits from feeding steers.

The results reported in this experiment are similar to those obtained by many feeders in Pennsylvania.

The financial results obtained in this test should not be taken as typical of what may be accomplished every year, as the price at which cattle are purchased and the market price of farm feeds and the selling price of the cattle are the determining factors. However, if reasonable prices can be obtained from the feeds grown on the farm by feeding cattle, it is often better to dispose of these crops in that way than to sell them on the market. When crops are sold from the farm each year, a large amount of fertility is lost to the farm which would remain if the crops were marketed through cattle. Not only would the fertility remain on the farm, but a market would be established for many unsalable farm crops.

Object.

The object of this experiment was to obtain additional information upon the feeding value of corn silage and mixed hay as roughage in feeding cattle. Also to further investigate the advisability of having the ration made up largely of roughage during the early part of the feeding period and of adding grain during the latter part. Previous experiments at this Station indicate that it is more desirable to feed a large amount of roughage during the early part of the feeding period and to add grain to the ration during the latter part. By this method of feeding, the daily gains made were not as large as when grain was fed the entire time, but the gains were made much cheaper than when considerable grain was fed during the early part of the feeding period. This experiment was carried on in line with the previous results obtained.

Cattle.

The cattle used in this trial were of mixed breeding with beef blood predominating. They were purchased in Roane County, West Virginia, and would have classed as fair feeders on the Pittsburgh market. Nearly all were two-year old cattle and averaged a little less than nine hundred pounds per head at the time the feeding trial was started. Thirty head were purchased, of which twenty-four were used for the experiment. The cattle were equally divided in so far as weight, quality, breed and type were concerned with twelve head in each lot.

Initial Cost of Cattle.

The thirty head of cattle were purchased for $1600.00, plus the freight charges of $64.00 from West Virginia to Lemont, Pennsylvania, which is near one of the college farms. In addition to this, a charge of $1.50 per head is allowed to pay for a month's pasture before they were put on the experiment. The thirty head of cattle on November 15 weighed 26,897 pounds which made the actual cost $6.28 per cwt. the day they were put on the experiment.

Shelter, Feed Lots and Water Supply.

These cattle were fed in an open shed enclosed on three sides and open to the south. The covered part of the shed, 14x30 feet, provides ample protection from rain and snow. An open pen, 25x30 feet, joins the shed, permitting the cattle to take some exercise. The open lots are cemented and have retaining walls which keep them from getting muddy during wet weather, but require considerable bedding to absorb the water.

Open galvanized tanks filled with water were kept before the cattle constantly. On account of the mild winter, little difficulty was experienced from freezing of the water.

Feeds and Method of Feeding.

The steers in Lot I were fed all the corn silage they would consume during the first two months of the feeding period. In addition to this they received three pounds of cottonseed meal per 1000 pounds live weight daily. At the end of fifty-six days, they were fed, in addition to this combination, all the ear corn they would consume. During the last two months they received shelled corn in place of ear corn as they would not consume a full feed of corn on the cob without wasting some of it. The individuals in Lot II received, as roughage, twenty pounds of corn silage and all the mixed hay they would consume during the first fifty-six days. In addition to this roughage, they received three pounds of cottonseed meal per 1000 pounds live weight daily. During the third month they received in addition all the ear corn they would consume. During the last two months they received shelled corn in place of ear corn.

The time of feeding was the same for both lots. They were fed at 6 A. M. and 4:30 P. M. each day. Lot I received half its silage at each feeding period and half its allowance of cottonseed meal. Lot II received its hay in the morning and silage in the evening. The cottonseed meal was all fed in the evening and not divided as in Lot I. The cottonseed meal was poured over the silage at the time of feeding. During the period in which grain was fed it was placed in the mangers prior to feeding the roughage. The ear corn was broken into pieces three to four inches in length so as to make it readily and completely consumable.

The quality of the feed used in the test was good. The silage was put up in a wooden stave silo from corn that was in the dent stage or fairly well matured. Because of the mild winter there was little trouble from the silage freezing in the silo which made it easy to handle. The mixed hay was grown on the College farm and was of good quality but had more timothy than was desirable for feeding steers. The ear and shelled corn was also grown on the College farm and most of it was well matured. The cottonseed meal was of a "choice" grade.

Price of Feeds.

The prices of the feeds used in the financial statement are such as prevailed in the vicinity of State College during the winter. Corn silage was valued at $3.50 per ton, mixed hay at $12.00 per ton, ear corn at 55c for a bushed of 72 pounds, shelled corn at 55c per bushel of 56 pounds and cottonseed meal at $31 per ton.

Weights and Weighing.

Each steer was weighed individually for three consecutive days at the beginning of the feeding trial. Individual weights were taken for three consecutive days for the initial weight at the end of fifty-six days, the roughage feeding period, and at the conclusion of the experiment. At the end of each four weeks, individual weights were taken on one day and group weights were taken on the day previous and following the day on which individual weights were obtained. Group weights were also taken in the middle of each four-week period. The weighing was always done at 9 A. M. without any change in the feeding and handling of the cattle.

Hogs in the Feed Lot.

A few hogs were put in the lots at the end of the first month but as the cattle were receiving no grain, except that found in the silage, it was necessary to supply additional feed. The hogs put in the lot were not first class and some were too small to make the most desirable type of hogs to follow cattle.

Table I.—Air Dry Moisture in Feeds*

	Nov. 29	Dec. 27	Jan. 24	Feb. 21	Mar. 21	Average Amount of Dry Matter in Feeds
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Ear corn			16.36			83.64
Cottonseed meal	8.25	6.31	6.31	8.26	9.82	92.21
Mixed hay	6.21	18.75	14.28	18.72	27.78	82.85
Corn silage	65.68	68.19	68.93	66.06	66.62	32.91
Shelled corn			15.73	17.39	18.61	82.76
Refused corn silage	71.00	67.10	67.40	74.16	66.26	30.82
Refused hay	6.37	20.86	22.12	23.00	35.90	78.35

***Reported by the Department of Experimental Agricultural Chemistry.**

Samples of feed were taken every month to the Laboratory of Experimental Agricultural Chemistry for air-dry moisture determinations. In studying Table I, it will be noted that the amount of moisture in the cottonseed meal, corn silage and shelled corn was quite uniform. The amount of moisture in the hay varied from 6.29 per cent. to 27.78 per cent., or a variation of 21.57 per cent.

Table II.—Feeds Offered and Refused.

Lot I--12 Steers

DATE	OFFERED				REFUSED		
	Corn silage	Cotton-seed meal	Ear corn	Shelled corn	Corn silage	Ear corn	Shelled corn
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Nov, 15-29	6800	302	......	......	63.50	......	
Nov. 29—Dec. 13	8125	432.5	......	......	46.75	......	
Dec. 13—Dec. 27	9050	482	.....	......	105.25	......	
Dec. 27—Jan. 10, 1913	7900	490	......	......	153.00	......	
Jan. 10—Jan. 24	5450	497.5	1575	......	141.00	......	
Jan. 24—Feb. 7	4077	504	2171	.....	87.00	186.50	
Feb. 7—21	3960	514	......	1903	11.25	......	15.00
Feb. 21—March 7	3500	532	......	1942	9.50	......	39.25
March 7—March 21	3500	532	......	1817	32.50	......	
March 21—April 4	3500	532	.....	1956	1.75	......	27.25
	55862	4818	3746	7618	651.50	186.50	81.50

Lot II--12 Steers

DATE	OFFERED					REFUSED			
	Corn silage	Mixed hay	Cotton-seed meal	Ear Corn	Shelled corn	Corn silage	Mixed hay	Ear corn	Shelled corn
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Nov. 15-29	3060	1750	302	....	....	30.50	31.71	......	
Nov. 29--Dec. 13	3360	1905	432	....	....	.....	63.00	.....	
Dec. 13—Dec. 27	3360	1750	481	....	...	......	39.50	......	
Dec. 27--Jan. 10, 1913.	3360	1660	490	....	....	......	97.25	......	
Jan. 10—Jan. 24	3360	1280	497	1575	..	......	134.75	3	
Jan. 24—Feb. 7	3360	830	504	2295	....	62.25	143.00	55.75	
Feb. 7-21	3360	700	513	....	1876	....	51.50	......	58.50
Feb. 21—March 7	3360	700	532	...	1947	93.50	72.75	.....	
Mar. 7—Mar. 21	3360	700	532	....	1551	130.25	32.50	.....	
Mar. 21—Apr. 4	3360	600	532		1644	17.50	......	......	76.50
	33300	11695	4815	3870	7018	334.00	666.00	58.75	135.00

By a study of Table II, which gives the amount of feed consumed and refused, it will be seen that Lot I was consuming the maximum amount of corn silage, as a small amount was refused each feeding period. Lot II received an average of about 20 pounds of corn silage per head daily and refused very little during the entire feeding period. The steers in Lot II were receiving all the hay they would consume in addition to this amount of silage as indicated by the amount refused, even though the amount was gradually decreased after the first month. It will also be noticed that the amount of roughage consumed materially decreased when grain was added to the ration. In Lot I, the amount of silage consumed decreased 1438 pounds during a two-week period when 1575 pounds of ear corn were added. The addition of corn to the ration did not decrease the appetite of the cattle for silage, but it became necessary to reduce the amount fed in order to get the cattle to eat a sufficient amount of grain. In Lot II, the amount of hay consumed decreased 327 pounds during the two-week period when 1575 pounds of corn were added to the ration. Lot I refused a considerable portion of the ear corn offered at the end of the third month of the feeding period. The steers would shell the corn and refuse to eat the cob. As soon as the shelled corn was substituted for the ear corn, very little was refused. Lot II consumed a little more ear corn than did Lot I but Lot I consumed 654 more pounds of shelled corn than did the cattle in Lot II.

Table III.—Showing Average Amount of Feed Consumed Daily per Head by Steers, November 15, 1912, to April 4, 1913, (28 Day Periods) 140 Days.

	Lot I.	Lot II.
First Period:	Lbs.	Lbs.
Corn silage	44.094	19.015
Cottonseed meal	2.185	2.185
Mixed hay	......	10.295
Ear corn	.....	......
Air dry matter	17.139	18.190
Second Period:		
Corn silage	49.676	20.00
Cottonseed meal	2.899	2.899
Mixed hay	......	9.750
Ear corn	......	......
Air dry matter	18.519	17.000
Third Period:		
Corn silage	27.673	19.801
Cottonseed meal	2.981	2.981
Mixed hay	......	5.416
Ear corn	10.594	11.372
Air dry matter	20.252	23.110
Fourth Period:		
Corn silage	22.14	19.702
Cottonseed meal	3.113	3.110
Mixed hay	......	3.794
Shelled corn	11.282	11.202
Air dry matter	19.692	21.879
Fifth Period:		
Corn silage	20.730	19.000
Cottonseed meal	3.166	3.166
Mixed hay	.....	3.772
Shelled corn	11.146	9.281
Air dry matter	18.848	19.377
Average for 140 Days:		
Corn silage	32.226	19.503
Cottonseed meal	2.869	2.866
Mixed hay	.....	6.606
Ear corn	2.119	2.274
Shelled corn	4.485	4.096
Air dry matter	18.99	19.111

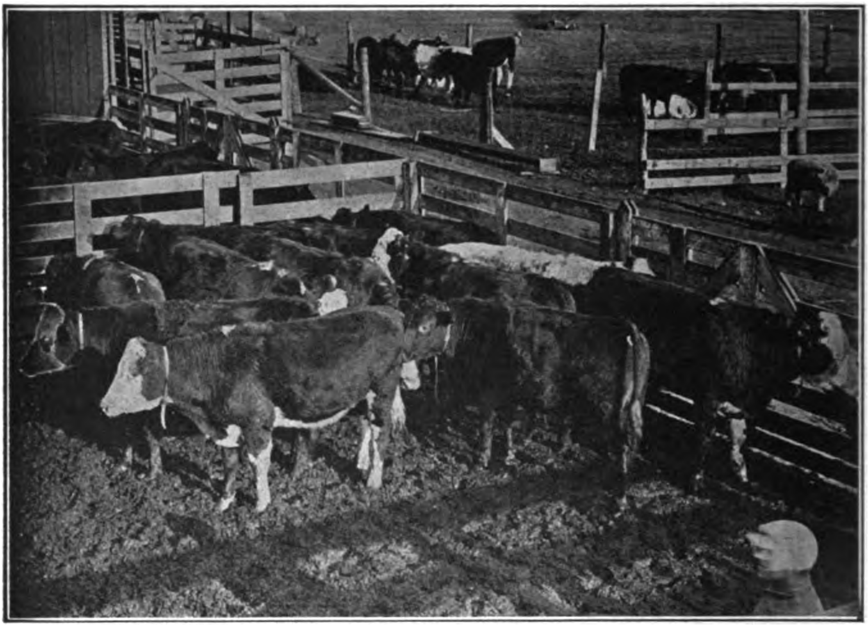

Fig. 1.—Lot 1 at the Beginning of the Feeding Period

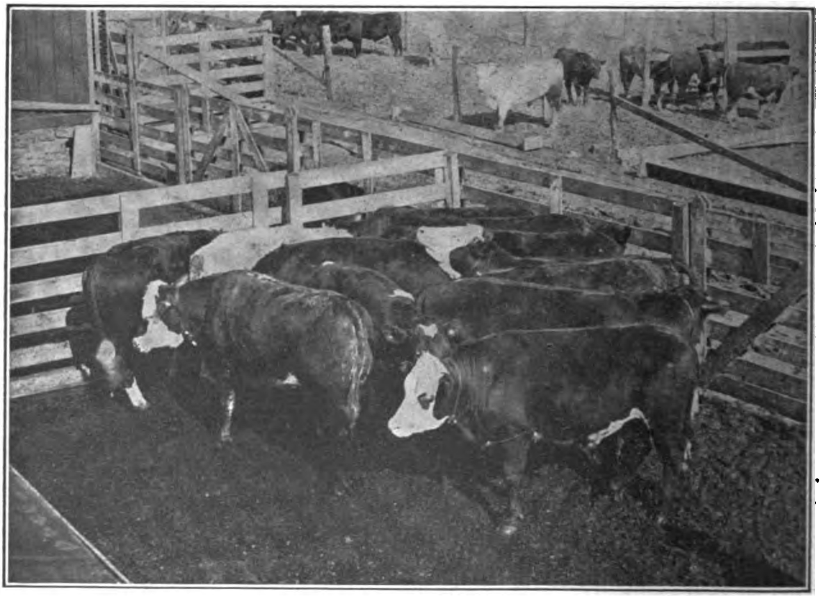

Fig. 2.—Lot I at the Close of the Feeding Period

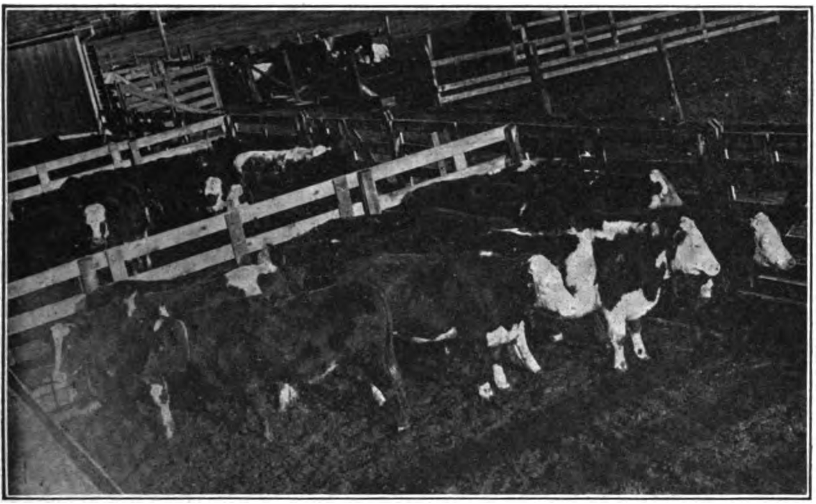

Fig. 3.—Lot II at the Beginning of the Feeding Period

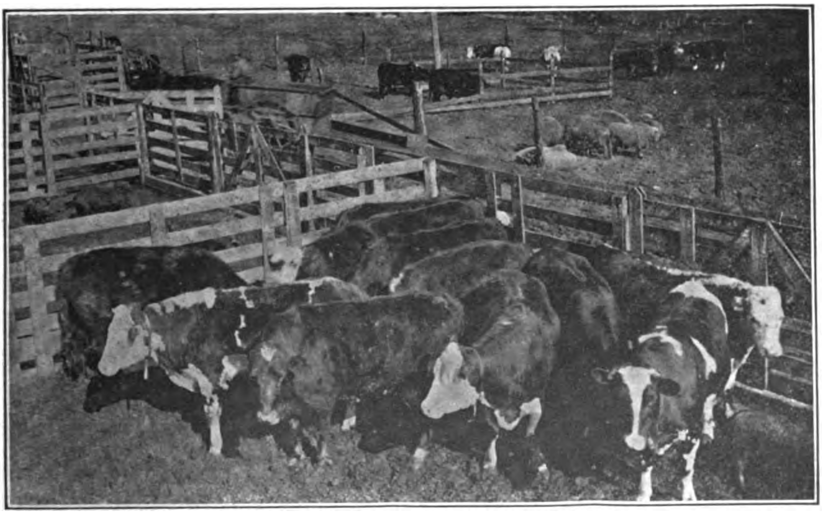

Fig. 4.—Lot II at the Close of the Feeding Period

Table III is presented to show the average amount of feed consumed daily per steer by twenty-eight day periods. The aim in feeding these cattle was to get them to take a maximum amount of roughage as soon as possible after the trial began. The steers in Lot I were to receive all the corn silage they would consume and those in Lot II were to have twenty pounds of corn silage and all the mixed hay they would consume. Lot II received 33 1-3 pounds per day at the beginning. On the fourth day the amount was increased to 41.66 pounds per head. This was increased to 45.5 pounds on the 11th day and raised to 50 pounds per head daily on the 20th day. Fifty pounds per head was the largest amount fed daily while the cattle were not receiving grain. The average daily consumption per steer in Lot II was eight pounds of mixed hay and fifteen pounds of silage during the first three days, after which the silage was increased to twenty pounds and the hay to ten pounds per head daily. On the tenth day the hay for Lot II was increased to twelve pounds daily per head which was the largest amount received at any time. At no time did these cattle show as keen an appetite for hay as for corn silage. At the beginning of the third period, ear corn was added to the ration which materially decreased the amount of roughage consumed. Both lots were started on 6½ pounds of ear corn per head daily.

This was increased at the rate of one-half pound per head daily until the steers were receiving twelve pounds per head in both lots at the end of two weeks. At the end of twenty days, after the ear corn was added to the ration, Lot I was receiving fourteen pounds per head daily and Lot II fifteen pounds. This amount of ear corn seemed to be all the cattle would consume in addition to the other feeds. At the end of 28 days shelled corn was fed in place of ear corn as they were beginning to refuse a portion of the latter.

There was little variation in the amount of shelled corn consumed during the fourth period, each lot consuming about eleven pounds per head daily. During the fifth period, Lot I consumed an average of about two pounds more per head than did Lot II.

The amount of dry matter consumed by Lot I during the different periods was very uniform with a variation of less than three pounds for the entire period. A difference of over five pounds was found in Lot II. The average for the entire period is very nearly the same, being slightly in favor of Lot I.

Table IV.—Average Daily Gain per Steer, by Periods.

	Lot I.		Lot II.	
	Lbs.	Lbs.	Lbs.	Lbs.
November 15—November 29	2.33	2.45	2.65	2.20
November 29—December 13	2.57		1.75	
December 13—December 27.	3.055	1.35	2.281	.952
December 27—January 10-13	.35		.377	
January 10—January 24....	3.26	2.147	3.07	2.74
January 24—February 7....	1.033		2.42	
February 7—February 21...	1.95	1.975	1.25	2.00
February 21—March 7......	2.00		2.75	
March 7—March 21........	1.48	1.838	1.37	1.365
March 21—April 4........	2.197		1.36	
November 15 to January 10, 56 days......		1.90		1.576
January 10 to April 4, 84 days........		1.987		2.035
Average, November 15 to April 4, 140 days.........		1.944		1.893

From Table IV, it will be noted that satisfactory gains were made by both lots from the beginning of the experiment to the end of the first six weeks, Lot I making an average gain of 2.655 pounds per head daily, while Lot II made a gain of 2.34 pounds per head daily. The cattle in both lots made no gain during the two weeks from December 27 to January 10, but showed a loss of .35 pounds per head daily in Lot I and .37 pounds per head daily in Lot II for that period. Since neither lot made any gains during that time, the cause in each case must be the same. During these two weeks the weather was very warm and much rain fell which may have been the cause of the cattle not doing well. The cattle in both lots seemed to lack appetite. Previous experiments indicate that after roughage alone has been fed for a time, the cattle seem to stop gaining satisfactorily unless grain of some kind is added to the ration. It is possible that the length of time that roughage alone could be fed to advantage to these cattle was six weeks instead of eight weeks as planned. As soon as ear corn was added to the ration both lots again made better gains and continued to gain to the end of the feeding period. The gains for the entire feeding period were more uniform in Lot I than in Lot II. The fluctuation of daily gains made was much greater in Lot II than in Lot I. Lot II also showed the greatest variation in the amount of feed consumed. The daily gains made by the cattle in Lot I for both the first and second periods were about the same. Lot II made nearly .5 of a pound greater gains during the second period than during the first period.

This would seem to indicate that silage is a more completely digestible food than mixed hay, since there was little difference in the amount of dry matter and other food nutrients consumed daily by the two lots.

Table V.—Average Weight and Gain of Steers.

No.	Lot I.			
	Final Weight	Initial Weight	Gain 140 Days	Daily Gain
	Lbs.	Lbs.	Lbs.	Lbs.
4............	1141.66	923.33	218.33	1.560
5............	1193.00	868.33	326.67	2.333
7............	1301.66	966.66	335.00	2.393
8............	1208.33	920.00	288.33	2.059
11............	1326.66	998.33	328.33	2.345
12.......	1235.00	936.66	298.34	2.131
16............	1293.33	906.66	386.67	2.762
19............	1045.00	901.66	143.34	1.024
28............	1145.00	891.66	286.67	2.048
43............	1108.33	916.66	191.67	1.362
63............	1003.33	775.00	228.33	1.631
72............	1085.00	836.66	248.34	1.774
Total.........	14,088.30	10,808.28	3280.02	

No.	Lot II.			
	Final Weight	Initial Weight	Gain 140 Days	Daily Gain
	Lbs.	Lbs.	Lbs.	Lbs.
1............	1293.33	958.33	335.00	2.393
2............	1208.33	885.00	323.33	2.309
3............	1011.66	838.33	173.33	1.248
13............	1080.00	831.66	248.34	1.774
14............	1093.33	923.33	170.00	1.214
17............	1303.33	955.00	348.33	2.488
20............	1266.66	996.66	270.00	1.929
21............	1223.33	975.00	248.33	1.774
22............	1281.66	930.00	351.66	2.512
61............	1116.66	868.33	248.33	1.774
62............	1201.66	916.66	285.00	2.036
67............	918.33	785.00	133.33	.950
Total.........	13,998.28	10,863.30	3134.95	

Table V shows the individual weights of the steers in both lots at the beginning and close of the feeding trial, the total gains made and the average daily gain made by the individual steers. It will be noted that at the beginning of the feeding trial, there were nine head in Lot I weighing over 900 pounds and eight in Lot II, but that those weighing between eight and nine hundred pounds in Lot II averaged more than those in Lot I. The total weight made the average of Lot II sixty pounds heavier than that of Lot I. In selecting the individuals for each lot it was deemed more desirable to have a uniform distribution of type, breed and conformation, even though there was a slight difference in the weight of the two lots. The cattle in each lot making the good gains were deep bodied, wide over the back and loin and possessed wide foreheads. Those making the smallest gains were individuals that were shallow bodied, narrow in the forehead and restless in the feed lot. Lot I shows greater uniformity in individual gains which corresponds to their behavior in the amount of dry matter and feed consumed during the different periods.

Table VI.—Showing Amount of Feed and Dry Matter Consumed Daily per Steer by Periods, Amount of Dry Matter per Pound of Gain, and Cost of Producing a Pound of Gain.

	Lot I.	Lot II.
First Period (56 Days):		
Corn silage	46.885 Lbs.	19.507 Lbs.
Cottonseed meal	2.542 "	2.542 "
Mixed hay	.....	10.024 "
Ear corn	....	.....
Air dry matter	17.829 "	17.595 "
Average daily grain	1.90 "	1.576 "
Air dry matter per pound of gain	9.383 "	11.164 "
Cost per pound of gain	6.45 Cents	8.39 Cents
Daily cost of feed	12.140 Cents	13.367 Cents
Second Period (84 Days):		
Silage	23.514 Lbs.	19.501 Lbs.
Cottonseed meal	3.087 "	3.086 "
Mixed hay		4.327 "
Ear corn	3.531 "	3.791 "
Shelled corn	7.476 "	6.827 "
Air dry matter	19.597 "	21.455 "
Average daily gain	1.987 "	2.035 "
Air dry matter per pound gain	9.875 "	10.453 "
Cost per pound gain	9.55 Cents	10.000 Cents
Cost of feed per day	18.837 Cents	20.3922 Cents
Daily gain entire period	1.944 Lbs.	1.805 Lbs.
Dry matter for pound gain entire period	10.08 "	10.853 "
Cost per pound gain entire period	8.31 "	9.215 "

Table VI shows the average amount of feed and dry matter consumed per head daily by periods, the air-dry matter necessary to produce a pound of gain, the cost of feed per head daily and the cost per pound of gain. During the first period, the steers in Lot I consumed more than twice as much corn silage as did those in Lot II. The steers in Lot II, however, consumed ten pounds of hay to take the place of 27 pounds of corn silage in order to obtain an equal amount of dry matter. 9.383 pounds of dry matter were required to produce a pound of gain in Lot I, while Lot II required 11.164 pounds, or 1.781 pounds more than Lot I. The daily cost of feed per steer in Lot I was 12.140 cents; Lot II 13.367 cents. The cost of producing a pound of gain during the first 56 days was 6.45 cents for Lot I and 8.38 cents for Lot II. This would indicate that mixed hay is not worth $12 per ton for fattening cattle when corn silage can be obtained for $3.50 per ton. During the second period, the steers in Lot I consumed only four pounds more corn silage per head daily than did those in Lot II, those in Lot II consuming 4.327 pounds of mixed hay in addition to the silage. The amount of ear corn consumed in each lot was nearly the same while Lot I consumed a small amount more of shelled corn than did Lot II. Lot II consumed approximately two pounds more of dry matter per head daily than Lot I. A greater amount of dry matter was required to make a pound of gain in Lot II than in Lot I.

It cost .045 cents more to put on a pound of gain, and the cost of feed per head daily was 1.5 cents higher, in Lot II than in Lot I. It will be noticed that there is a marked difference in the cost per pound of gain in the two periods, due to the cheapness of the feed consumed and also to the fact that, in the early part of the feeding period, muscle tissue is being rebuilt and water is added to the body. During the latter part of the feeding period, fat is put on, which requires a concentrated grain feed, making the ration more expensive.

Valuation and Sale of Cattle.

At the close of the experiment, April 4, Mr. E. S. Bayard, of Pittsburgh, placed a value upon the cattle based upon the Pittsburgh market at that time. He valued both lots at $8.50, stating that there was not enough difference in the condition or finish of the two lots to make a difference in the price. Lot I showed a sleeker coat than did Lot II but it seemed that Lot II carried a little more flesh. The two lots of cattle were sold on the College farm to Altoona (Pennsylvania) butchers at $8.20 per hundred with 3% shrinkage, cattle weighed on full feed. They valued both lots alike and stated that from a butcher's standpoint there was no difference in the two lots. The cost of shipping and other expenses of putting cattle from State College on the Pittsburgh market is thirty-five cents per cwt. This expense was estimated in selling the cattle on the basis of the Pittsburgh market.

Table VII.—Summary of Feeding Experiment.

RATION	Lot I. 12 Steers	Lot II. 12 Steers
	Corn Silage Cottonseed Meal Ear Corn Shelled Corn	Corn Silage Mixed Hay Cottonseed Meal Ear Corn Shelled Corn
Initial value	$ 6.28	$ 6.28
Initial weight	10,808.33 Lbs.	10,863.33 Lbs.
Final weight	14,088.30 "	13,998.28 "
Total gain	3,279.77 "	3,134.95 "
Average daily gain	1,944 "	1.803 "
Feed Consumed:		
Silage	55,210.50 "	32,891.82 "
Mixed hay		11,029.00 "
Cottonseed meal	4,818.00 "	4,816.00 "
Ear corn	3,559.50 "	3,811.25 "
Shelled corn	7,536.50 "	6,983.00 "
Daily Feed per Steer:		
Silage	32.266 "	19.503 "
Mixed hay		6.606 "
Cottonseed meal	2.869 "	2.863 "
Ear corn	2.119 "	2.274 "
Shelled corn	4.485 "	4.096 "
Cost of Feed per Lot:		
Silage	$96.832	$57.56
Mixed hay		$66.174
Cottonseed meal	$74.68	$74.63
Ear corn	$27.194	$29.117
Shelled corn	$74.001	$68.575
Cost of Feed	$272.707	$296.56
Cost of gain per cwt	$8.31	$9.46
Necessary selling value per cwt	6.753	6.992
Actual selling price in lots plus 3% shrinkage	8.20	8.20
Initial value per steer	56.56	56.851
Cost of feed per steer	22.725	42.71
Selling value per steer	93.38	92.785
Profit per steer not including pork	14.095	11.224
Price received from a bushel of corn after paying for other feeds	$1.469	$1.308
Prices received for feeds when fed to beef cattle:		
Corn silage per ton	$5.69	$5.09
Mixed hay per ton		17.45
Cottonseed meal per ton	49.79	45.05
Corn per bushel	$ .8911	$ .799

*Based upon corn silage at $3.50 per ton; mixed hay $12 per ton; cottonseed meal $31 per ton, and corn at 55 cents per bushel.

A summary of this experiment shows that the feeding of corn silage alone as a roughage was the more satisfactory of the two methods of feeding. In this lot the gains were made more cheaply and larger daily gains were obtained than were made by the cattle receiving corn silage and hay for a roughage. The cost of producing one hundred pounds of gain was greater in Lot II than in Lot I. This is, however, due to the fact that mixed hay is more expensive at $12.00 per ton than is corn silage at $3.50 per ton. The experiment also bears out the results of previous experiments at the Station, which indicate that when light weight cattle of about 900 pounds are put on roughage during the early part of the feeding period they will make economical gains even though it may be done at smaller gains per head daily.

The cost of producing one hundred pounds of gain in Lot I was 1.15 cents less than that of Lot II. This difference was in a measure due to the irregular gains made by Lot II and also the price charged for hay. The necessary margin between the buying and selling prices of the two lots was 47 cents in Lot I and 71 cents in Lot II. The price received for each bushel of corn consumed after paying the average market price for the other feeds was $1.469 for Lot I, and $1.308 for Lot II. Allowing a proportionate increase in value for all feeds fed from the profits on the cattle the returns are as follows:

Lot I.

Corn Silage	$ 5.69	per ton.
Cottonseed Meal	49.79	per ton.
Corn	.8911	per bushel.

Lot II.

Corn Silage	$ 5.09	
Mixed Hay	17.45	
Cottonseed Meal	45.05	
Corn	.799	per bushel.

The hogs in Lot I gained 611 pounds while following the cattle. In addition to the droppings from the steers, they received 2160 pounds of a grain mixture of corn and tankage. Valuing the additional feed at $25 per ton, they made a profit of $30.12 from following the cattle. The hogs in Lot II gained 575 pounds. They also received 2160 pounds of grain in addition to what they were able to pick up in the feed lot. This lot of steers made a profit from hogs following them of $26.76 or $2.23 per head. Adding this to the profit from actual feeding, the net profits from Lot I are $199.26 and for Lot II $151.44.

No account was kept of the amount of manure produced or the bedding used. The manure produced should pay for the bedding used and for the labor required to feed the cattle. When farm grown feeds are fed to cattle and home market prices are allowed for the feed, the labor of handling is paid for, as in such instances fully as much labor is required to handle the feed in hauling it to market as is required when feeding it to cattle.

The results of this experiment again demonstrate that cattle feeding is a profitable business in Pennsylvania. It may not be possible to make such large profits each year, but it means a steady market for some forms of roughage that can be but should not be sold from the farm. It further demonstrates that corn silage is one of the most valuable roughages that can be obained for feeding beef cattle.

Sci 1638.5.4

The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 125

VARIETY TESTS OF WHEAT

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
OCTOBER, 1913.

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The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 125

TESTS OF VARIETIES OF WHEAT

By CHARLES F. NOLL

For twenty-three years the Pennsylvania Experiment Station has carried on comparative tests of varieties of winter wheat. Five varieties have been tested continuously ever since the work was begun, though only eleven of the varieties have been grown over ten years. Varieties which have not yielded well or which are no longer on the market and have no especial merits are as a rule discontinued after a trial of a few years. New varieties which are advertised by seedsmen are secured and compared with old standard varieties.

The chief aim in this work is to determine the relative yielding capacity of the varieties tested but observations are made on the resistance to disease, stiffness of straw, earliness, injury from Hessian fly and ability to withstand winter killing. No attempt has been made, except with a few varieties, to determine in an experimental way the milling and baking qualities of these varieties.*

The soil on which the varieties have been tested is Hagerstown clay loam. This is underlaid with limestone and is well drained. It is in a good state of fertility and is naturally a good wheat soil. On the Experiment Station Farm four fields have been used for variety tests of potatoes, oats and wheat. These crops are grown in the order named, and the fourth field is planted in clover and timothy to complete the rotation. The fertilization of these fields has been as follows: Seven to ten tons of manure are applied for potatoes in the winter or early spring, 160 to 200 pounds acid phosphate for the oats, and seven to ten tons manure and 160 to 200 pounds acid phosphate for the wheat.

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*See Pa. Expt. Station Bulletin No. 97 and Annual Report of The Pa. State College for 1909-1910, "Milling and Baking Tests," by F. D. Gardner.

The fields devoted to variety testing are 140 ft. wide and as a rule the plats consist of two drill widths across the field. This made the plats eleven feet wide and when they were trimmed up at the ends they comprised from one-twenty-eighth to one-thirteenth of an acre each. Sometimes, because of scarcity of space, the varieties sown last were sown in single drill widths.

Previous to 1908, the varieties were sown in duplicate and with no checks. Since 1908, a standard variety has been used as a check and repeated every third or every fourth place.

This report gives the yields for the years 1910 to 1912, inclusive, with the average yields for a number of years. The records for previous years are contained in Bulletins 6, 39, 46, 55, 67, 76, 82 and 94.

In the tables, "corrected yields" are reported. This method of computing results in plat work was used in Bulletins 94, 98, 108 and 119 and is described in Bulletin 94, page 6, and in Bulletin 108, page 5.

Test in 1909 and 1910

The field which had been in oats, was plowed and rolled Aug. 21. It was manured with 6 to 7 tons of manure per acre Aug. 29. On the same date it was harrowed twice with a spring harrow. On Sept. 11, the ground was again harrowed and the wheat was seeded at the rate of two bushels per acre except in the case of the variety Turkey Red which was sown at the rate of 1½ bushels per acre. This variety has very small grains and when sown at the rate of two bushels, as it was in other years, it was too thick. When the wheat was seeded, acid phosphate was applied at the rate of 160 lbs. per acre. The ground was in fine condition for seeding. The wheat during the early part of the winter was in fine condition but during most of January and February the ground was covered with several inches of ice and this caused a great deal of injury. In places, all the plants were dead. There seemed to be little relation between the variety and the extent of injury except that Turkey Red and the spring wheat suffered more than the others. The injury varied chiefly with the topography. On some plats the wheat was entirely destroyed on one-third of the area. Because the wheat was entirely killed in spots it seemed impossible to get relative yields with any degree of accuracy. However, the areas entirely destroyed were deducted from the total areas of the plats and the yields computed on the basis of what was left. Timothy had been sown with the wheat and where the latter was injured the timothy was quite large. On this account the apparent yield of straw was exaggerated. For the reason given, the results for this year can scarcely be relied upon and though they are reported here they are omitted in computing the average yields.

The wheat was cut July 13 and threshed July 21. The yields on the areas not entirely destroyed by the ice are reported in Table I which follows:

Table I.—Yields per Acre of Varieties of Wheat in 1910.

	VARIETY	Actual Yields		Corrected Yields		Wt. per measured bushel Lbs.
		Grain Bu.	Straw Lbs.	Grain Bu.	Straw Lbs.	
1	Harvest King — Check..	30.5	2718	31.6	3143	61.0
2	Reliable	26.9	2592	29.0	2920	60.8
3	Ontario Wonder.........	27.1	2920	30.4	3369	61.0
4	Dawson's Golden Chaff..	22.9	2268	26.8	2613	57.8
5	Check	25.8	2731			
6	Dietz Longberry Red.....	24.2	4081	28.6	4427	60.5
7	Fultz	21.5	4034	24.7	4143	60.5
8	Four-rowed Fultz........	22.5	4021	25.0	3913	59.5
9	Check	29.2	3397			
10	Beechwood Hybrid......	29.5	4051	29.7	3628	61.0
11	Forty Fold or Gold Coin..	34.7	3337	32.6	2896	59.5
12	Turkish Amber..........	30.6	3290	26.9	2770	60.8
13	Check	38.1	3844			
14	Rochester Red..........	25.8	4031	22.5	3532	59.4
15	Funk's Turkey Red.....	21.7	3067	20.1	2893	61.4
16	Fulcaster	26.1	3471	25.6	3544	60.8
17	Check	30.1	2822			
18	Lancaster Fulcaster.....	27.0	3215	27.9	3534	61.5
19	Martin Amber...........	21.8	3271	22.8	3527	60.5
20	Jones' Longberry No. 1..	26.2	2428	27.3	2667	61.0
21	Check	30.4	2968			
22	China..................	32.2	3625	33.0	3744	61.0
23	Currell's Prolific........	23.6	2784	23.8	2803	60.2
24	Councilman	21.5	2708	21.5	3208	61.0
25	Check	31.9	3259			
26	Wyandotte Red..........	31.3	3433	30.1	3288	61.0
27	Eclipse	33.7	2850	31.6	2787	61.0
28	Fultzo-Mediterranean ..	29.3	2834	26.6	2790	60.0
29	Check	35.6	3170			
30	Spring*	18.3	2884	15.7	2749	58.0
31	Gypsy	25.5	2743	21.2	2371	61.4
32	Poole	34.5	3688	27.8	3264	60.8
33	Check	40.3	3679			
34	Nigger	30.4	3175	25.2	2935	60.0
35	"Glace"	32.0	3913	28.0	3941	59.0
36	Check	33.8	2841			

*A variety of spring wheat grown as a winter wheat.

Test in 1910 and 1911

The field for the wheat varieties was plowed August 19 and 20. It was fitted for seeding by harrowing once, August 20, with a spring harrow, and twice September 16. On September 17 the wheat was sown at the rate of two bushels per acre and acid phosphate was applied at the rate of 160 lbs. per acre.

The wheat started well in the fall and came through the winter without winter killing. There was some injury from the Hessian fly which reduced the yield slightly.

Table II.—Yields per Acre of Varieties of Wheat in 1911.

	VARIETY	Actual Yields		Corrected Yields		Wt. per measured bushel Lbs.
		Grain Bu.	Straw Lbs.	Grain Bu.	Straw Lbs.	
1	Harvest King — Check..	27.5	1800	29.5	1452	61.7
2	Reliable	28.0	1617	29.6	1301	61.0
3	Ontario Wonder.........	26.2	981	27.4	786	61.2
4	Check	28.5	1815			
5	Dawson's Golden Chaff..	26.8	1392	27.5	1239	60.2
6	Dietz Longberry Red....	29.2	1693	29.6	1702	62.2
7	Fultz	24.6	1674	24.7	1920	61.0
8	Four-rowed Fultz........	24.5	1383	24.3	1845	60.5
9	Check..................	30.0	900			
10	Beechwood Hybrid......	26.3	1872	26.0	2971	60.5
11	Forty Fold or Gold Coin..	22.7	2316	22.7	3616	59.0
12	Turkish Amber..........	33.6	2487	33.9	3821	61.5
13	Check	29.0	960			
14	Rochester Red..........	23.6	1737	23.9	2209	59.0
15	Fulcaster	38.8	3075	39.2	3370	61.5
16	Lancaster Fulcaster.....	22.0	1683	22.2	1622	61.7
17	Check	29.4	1689			
18	Jones' Longberry No. 1..	28.9	2166	29.3	1902	61.5
19	China..................	32.3	2337	33.8	2099	61.2
20	Currell's Prolific........	31.3	2472	33.6	2270	60.5
21	Check.................	26.8	1545			
22	Councilman	27.1	1074	28.3	1125	62.0
23	Wyandotte Red.........	25.8	2352	25.7	2783	62.2
24	Eclipse	28.7	906	27.3	1232	61.5
25	Check	32.4	909			
26	Fultzo-Mediterranean ..	27.3	1215	25.5	1786	60.5
27	Gypsy	28.5	2115	27.0	2851	62.5
28	Poole	27.4	1809	26.9	2262	61.0
29	Check	29.3	1245			
30	Nigger	29.0	1410	28.5	1361	61.0
31	"Glace"	27.2	2043	26.1	1683	60.7
32	Mealy..................	28.0	1923	26.3	1392	60.1
33	Check	32.0	2280			
34	Red Wave..............	21.5	3213	20.3	2290	59.0
35	St. Louis Grand Prize...	24.7	1521	24.0	1242	58.7
36	Acme Bred.............	28.9	2016	28.8	1918	61.0
37	Check	28.8	1275			

Test for 1911 and 1912

The field in which the varieties of wheat were to be sown was manured August 17 and plowed a few days later. The field was not harrowed and by the 26th of September the volunteer oats were so large that the field was replowed to a shallow depth with a gang plow. The ground was fitted for seeding by rolling and harrowing and the wheat was sown September 28. Acid phosphate was applied at the rate of 160 lbs. per acre when the wheat was sown. As usual the rate of seeding was two bushels per acre except that the variety Acme Bred was sown in a plat at the rate of one bushel per acre as well as in one at the rate of two bushels per acre. The plat sown at the rate of one bushel per acre was included at the request of the seedsman who originated and distributed this variety.*

The wheat was sown later than usual but made a fair growth before winter. It was, however, not nearly as large as usual and had not tillered as much. It remained thin on the ground and gave low yields. The wheat was cut July 16 and threshed July 31 and August 1 and 2. The yields per acre are given in Table III which follows:

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*S. M. Schindel, Hagerstown, Md.

Table III.—Yields per Acre of Varieties of Wheat in 1912.

	VARIETY	Actual Yields		Corrected Yields		Wt. per measured bushel Lbs.
		Grain Bu.	Straw Lbs.	Grain Bu.	Straw Lbs.	
1	Harvest King — Check..	16.0	2770	15.7	2503	59.75
2	Reliable	19.0	2734	18.8	2672	60.00
3	Ontario Wonder.........	25.5	3064	25.5	3129	59.00
4	Dawson's Golden Chaff...	26.2	3447	26.4	3685	57.57
5	Check	15.4	2231			
6	Dietz Longberry Red.....	17.5	2683	17.6	3122	61.00
7	Fultz	21.3	3028	21.3	3665	61.25
8	Four-rowed Fultz.......	20.1	1808	19.8	2224	60.50
9	Check	16.0	1909			
10	Beechwood Hybrid......	26.3	2583	24.7	3270	59.50
11	Forty Fold.............	27.9	2770	25.3	3390	58.50
12	Turkish Amber.........	23.4	2468	20.4	2937	61.00
13	Check	18.6	2181			
14	Rochester Red..........	23.8	2899	21.7	3150	60.00
15	Fulcaster	21.5	3014	21.3	3110	61.00
16	Lancaster Fulcaster.....	17.2	2124	18.9	2087	60.25
17	Check	12.9	2669			
18	Jones' Longberry No. 1.	18.2	2784	21.5	2604	60.00
19	China	18.2	3214	20.5	2998	59.00
20	Currell's Prolific.........	18.3	2267	20.1	2108	60.00
21	Check	14.8	2698			
22	Councilman	19.8	2683	20.3	2386	61.00
23	Wyandotte Red..........	21.3	2138	21.2	1827	60.00
24	Eclipse	21.5	2870	20.8	2366	59.50
25	Check	16.7	3157			
26	Fultzo-Mediterranean ...	18.9	2597	18.1	2116	59.25
27	Gypsy	23.9	3444	23.5	2888	60.25
28	Poole	23.6	2555	23.6	2206	60.00
29	Check	15.3	2813			
30	Nigger	25.6	2770	26.3	2464	59.50
31	"Glace"	19.8	2970	20.3	2642	58.25
32	Mealy	21.8	2727	22.4	2390	58.00
33	Check	15.3	2813			
34	Red Wave..............	26.3	3014	26.1	2892	58.50
35	St. Louis Grand Prize...	24.6	3114	24.8	3228	58.25
36	Check	15.8	2210			
37	Check	15.8	3071			
38 39	Acme Bred..............	25.8	2382	24.3	2172	60.3
40	——————...............	——	——	——	——	——
41	Check	18.2	2066			

Test in 1912 and 1913

On account of enlarging the variety fields and the addition of three new ones, the wheat varieties were sown in 1912 in a field never before devoted to experimental work. It had been, however, cropped uniformly in a rotation of clover and timothy, corn, oats and wheat. As a rule, a good application of manure had been applied to the sod for the corn and when the oats and wheat were sown, 160 to 200 lbs. acid phosphate per acre were applied for each crop. The treatment of this field was essentially like that used on the old variety fields except that here corn followed clover and timothy, while in the old variety fields potatoes followed the clover and timothy. This field was in oats in 1912.

The field was manured in August at the rate of about 8 tons per acre and then plowed. When the wheat was sown September 19 and 20, acid phosphate was applied at the rate of 200 lbs. per acre.

The rate of seeding was two bushels per acre except for the Acme Bred and Miracle which were sown both at the rate of 2 bushels per acre and one bushel per acre. These varieties, the seedsmen* who are selling them claim, should be sown at low rates per acre to get best results. A glance at the table will show that the higher rate of seeding gave a greater net return than the lower rate. The wheat came up well and made a fine growth before winter. There was scarcely any winter injury and very little damage from the fly. Two hard frosts June 9 and June 10 caused some injury. This was quite marked in Rochester Red plat where many heads did not mature more than half as many grains as they should have normally. Fulcaster was injured to a somewhat less extent. None of the other varieties seemed to be injured but there is little doubt that there was more or less damage on many of the plats.

The wheat was cut July 10, and threshed July 28 and 29.

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*Acme Bred supplied by S. M. Schindel, Hagerstown, Md. The lot designated as "b" was claimed to be an improvement over the other lot originated earlier. They are quite distinct varieties. S. M. Schindel has been succeeded by Scott & Matthews, Hagerstown, Md.

Miracle bought from W. J. Massey, Prices, Md., formerly sold by Stoner Seed Co., Fincastle, Va.

Table IV.—Yields per Acre of Varieties of Wheat in 1913.

	PLAT	Actual Yield		Corrected Yield		Wt. per measured bushel Lbs.
		Grain Bu.	Straw Lbs.	Grain Bu.	Straw Lbs.	
1	Harvest King — Check..	19.5	4321	36.1	3938	60.4
2	Reliable	24.4	3491	39.9	3459	61.4
3	Ontario Wonder.........	22.4	3711	32.9	4270	60.8
4	Check	27.2	3283			
5	Dawson's Golden Chaff.	34.2	2719	44.1	3096	58.9
6	Dietz Longberry Red.....	27.2	4725	34.1	5123	59.8
7	Check	29.6	3807			
8	Fultz	25.9	4225	29.9	4413	60.5
9	Four-rowed Fultz.........	23.4	3367	25.6	3560	60.0
10	Check	34.7	3699			
11	Beechwood Hybrid......	23.8	5939	24.8	6296	59.3
12	Forty-Fold or Gold Coin.	24.9	3708	26.2	3920	59.3
13	Check	33.9	3745			
14	Turkish Amber..........	29.1	3919	30.3	4174	60.8
15	Rochester Red..........	22.9	3277	23.3	3537	60.0
16	Check	36.3	3601			
17	Fulcaster	29.1	3338	27.3	3485	59.0
18	Lancaster Fulcaster.....	30.1	3829	28.5	3824	60.4
19	Check	39.0	4115			
20	Jones' Longberry No. 1..	28.1	4124	26.6	4027	60.8
21	China	33.5	4031	32.6	4019	60.0
22	Check	36.2	3868			
23	Currel's Prolific.........	35.4	4237	35.3	4634	59.8
24	Councilman	31.3	4191	31.2	4670	60.3
25	Check	36.2	3465			
26	Wyandotte Red.........	33.4	4169	32.7	4299	60.0
27	Eclipse	28.9	3321	27.7	3141	58.0
28	Check	38.2	4497			
29	Fultzo-Mediterranean ...	27.0	3147	26.0	3053	58.9
30	Gypsy	23.7	2913	23.2	3172	61.8
31	Check	36.2	3176			
32	Poole	35.4	3655	34.4	4135	60.3
33	Nigger	30.0	3112	28.4	3236	59.0
34	Check	39.2	4092			
35	Glace	31.6	3884	28.8	3739	60.8
36	Mealy	33.9	5043	30.7	5036	58.8
37	Check	40.3	4167			
38	Red Wave..............	36.1	4771	32.8	4713	59.0
39	St. Louis Grand Prize....	40.4	4074	39.0	4217	59.5
40	Check	35.9	3623			
41	Acme Bred a...........	33.3	4374	32.9	4671	60.0
42	Acme Bred b...........	20.8	2350	20.2	2467	61.3
43	Check	37.9	3815			
44	Miracle	33.6	4665	30.8	4473	60.2
45	Klondyke	37.2	3988	32.9	3577	58.4
46	Check	42.3	4662			
47	Acme Bred, a 1 bu. per A.	31.7	3774	27.9	3382	
48	Acme Bred, b, 1 bu. per A.	20.4	2086	18.9	1991	
49	Miracle, 1 bu. per A......	28.6	3350	25.5	3419	
50	Check	37.1	3591			

Average Yields

Because of the great difference in the relative yields of the different varieties tested in the different years, not much dependence as a rule can be placed upon the merits of a variety after a trial of only one or two years, and for this reason the two tables which follow, giving the average yields for 4 years and the average yields for all years grown, are given. It will be noted that in computing these average yields, the yields secured in 1910 are omitted. This is because of the injury by ice as noted before. The yields of 1904 are omitted from the second of these tables because, during the winter preceding, ice injured the wheat even more than in 1910 and added to this there was considerable damage done by the Hessian fly.

In the second of these tables all varieties are compared with Reliable. This is a standard variety which has been grown ever since the variety testing was begun.

Average Yields of Varieties of Wheat for 1909 to 1913, Omitting 1910—4 years.

VARIETY	YIELD PER ACRE Grain Bu.	YIELD PER ACRE Straw Lbs.	Weight per measured bu.
Dawson's Golden Chaff	32.3	2291	59.0
Turkish Amber	32.2	3752	61.4
Fulcaster	29.7	3458	61.1
Ontario Wonder	29.4	3422	60.6
Currell's Prolific	29.4	2999	60.7
China	29.2	3320	60.3
Harvest King	29.0	2940	61.1
Reliable	28.9	2579	61.0
Eclipse	28.6	2524	60.2
Dietz Longberry Red	27.7	3178	61.3
Wyandotte Red	27.7	3259	61.3
Beechwood Hybrid	27.1	3829	60.2
Jones' Longberry No. 1	26.9	3072	60.9
Councilman	26.6	2719	61.3
Fultz	26.2	3314	61.1
Forty Fold or Gold Coin	26.0	3224	59.2
Fultzo-Mediterranean	25.6	2750	60.2
Rochester Red	25.3	3051	59.8

Average Yields of Varieties of Wheat for All Years Tested, Omitting 1904 and 1910, Compared With Reliable

VARIETY	Yield per Acre		Increase or Decrease per A. over Reliable		Wt. per measured bushel Lbs.
	Grain Bu.	Straw Lbs.	Grain Bu.	Straw Lbs.	
22 years—1890-1913:					
Reliable	30.3	3401			61.9
Fulcaster	31.3	3231	1.0	-170	62.2
Ontario Wonder	29.4	3072	- .9	-329	61.6
Dietz Longberry Red	29.3	3470	-1.0	69	62.2
Fultz	28.0	2217	-2.3	-1184	61.6
16 years—1896-1913:					
Reliable	29.6	3253			61.9
Forty Fold or Gold Coin	28.8	3019	- .8	-234	59.9
Rochester Red	27.7	3072	-1.9	-181	60.3
15 years—1897-1913:					
Reliable	29.4	3216			61.5
Dawson's Golden Chaff	32.2	2832	2.8	-384	59.5
13 years—1899-1913:					
Reliable	28.7	2988			61.3
Harvest King	29.6	2836	.9	152	61.6
12 years—1900-1913:					
Reliable	29.0	3068			61.4
Beechwood Hybrid	27.8	3254	-1.2	188	61.1
11 years—1901-1913:					
Reliable	29.6	3028			61.0
Jones' Longberry No. 1	28.7	3101	.9	73	61.1
10 years—1902-1913:					
Reliable	30.0	2992			61.1
Turkish Amber	30.4	3494	.4	502	69.9
8 years—1905-1913:					
Reliable	30.2	3199			60.9
China	31.5	3581	1.3	382	60.5
5 years—1908-1913:					
Reliable	31.3	2873			60.2
Wyandotte Red	30.4	3372	- .9	499	61.3
Eclipse	27.7	2821	-3.6	-52	60.2
Fultzo-Mediterranean	25.5	2714	-5.8	-159	60.1
4 years—1909-1913:					
Reliable	28.9	2579			61.0
Currell's Prolific	29.4	2999	.5	402	60.7
Councilman	26.6	2719	-2.3	140	61.3
3 years—1911-1913:					
Reliable	29.4	2478			60.8
25-08**	31.9	3175	2.5	697	60.0
18-08**	30.8	3056	1.4	578	58.9
34-08**	30.6	2770	1.2	292	59.6
32-08**	30.3	3298	.9	820	59.8
St. Louis Grand Prize	29.3	2896	- .1	418	58.8
Acme Bred	28.7	2921	- .7	442	60.4
Poole	28.3	2867	-1.1	389	60.4
Nigger	27.7	2354	-1.7	-124	59.8

Average Yields of Varieties of Wheat---Continued

VARIETY	Yield per Acre		Increase or Decrease per A. over Reliable		Wt. per measured bushel Lbs.
	Grain Bu.	Straw Lbs.	Grain Bu.	Straw Lqs.	
3-08**	26.6	3520	-2-8	1042	60.9
Mealy	26.5	2939	-2.9	461	59.0
Red Wave..................	26.4	3301	-3-0	823	58.8
"Glace"***	25.1	2688	-4.3	210	59.9
Gypsy	24.6	2970	-4.8	492	61.4
Lancaster Fulcaster	23.2	2511	-6.2	33	60.8
Four-rowed Fultz...........	23.2	2543	-6.2	65	60.3

**These are selections. They were grown with the other varieties, but were not reported with the yields for the different years, for a great many others were not promising and were discontinued. 3-08 is a selection from Reliable; 19-08 and 25-08 from Dawson's Golden Chaff; 32-08 and 34-08 from Royal Red Clawson.

***This is a variety secured from H. M. Glace, Shickshinny, Pa. It is not known what variety it is.

TABULAR DESCRIPTION OF VARIETIES

VARIETY	Bearded or smooth	Color of grain	Color of chaff	Color of upper part of straw	Height in feet, average 1909-1913	Mean date of ripening	Stiffness of straw	Notes
Reliable	Bearded	Red	White	Light yellow	3.9	July 10	Rather weak	
Ontario Wonder	Smooth	Red	White	Light yellow	3.9	July 11	Fairly stiff	
Dawson's Golden Chaff	Smooth	White	Brown	Light yellow	3.5	July 9	Stiff	A high yielding quality.
Dietz Longberry Red	Bearded	Red	White	Purple	3.8	July 9	Medium Stiff	
Fultz	Smooth	Red	White	Light purple	3.7	July 7	Fairly stiff	
Beechwood Hybrid	Smooth	Red	Brown	Purple	3.5	July 9	Fairly stiff	
Forty Fold or Gold Coin	Smooth	White	Brown	Purple	3.7	July 9	Fairly stiff	
Turkish Amber	Bearded	Red	White	Purple	3.9	July 11	Rather weak	
Rochester Red	Smooth	Red	Brown	Purple	3.9	July 11	Fairly stiff	A high yielding variety. Quality good.
Fulcaster	Bearded	Red	White	Light purple	4.0	July 9	Rather weak..	
Harvest King	Smooth	Red	Brown	Light purple	3.7	July 9	Fairly stiff	
Jones' Longberry No. 1	Bearded	White	Brown	Light yellow	4.2	July 11	Rather weak	
China	Smooth	Red	Brown	Purple	4.1	July 10	Rather weak	Has yielded very well.
Fultzo-Mediterranean	Smooth	Red	White	Purple	3.6	July 10	Stiff	Low in yield.
Eclipse	Bearded	Red	Brown	Light yellow	4.0	July 10	Rather weak	
Wyandotte Red	Smooth	Red	White	Purple	3.8	July 8	Fairly stiff	
Councilman	Smooth	Red	Brown	Purple	3.7	July 7	Fairly stiff	
Currell's Prolific	Smooth	Red	Brown	Purple	4.0	July 8	Rather weak	Has yielded well.
					1910-1913			
Reliable	....	....	....	....	3.8	July 9		
Gypsy	Bearded	Red	White	Light yellow	3.9	July 11	Medium stiff	
Poole	Smooth	Red	Brown	Purple	3.7	July 8	Rather weak	
Nigger	Bearded	Red	White	Light purple	3.6	July 8	Fairly stiff	Has yielded well.
"Glace"	Smooth	Red	White	Light yellow	3.8	July 10	Stiff	Not properly named.
Four-rowed Fultz	Smooth	Red	White	Light purple	3.2	July 7	Stiff Rather weak	Much like Fultz and Fulcaster. Have not yielded as well.
Lancaster Fulcaster	Bearded	Red	White	Light purple	3.8	July 8		
					1911-1913			
Reliable	....	....	....	....	3.9	July 9		
Mealy	Smooth	Red	Brown	White	3.6	July 7	Stiff	Chaff fuzzy.
Red Wave	Smooth	Red	Brown	Yellow	3.7	July 9	Fairly stiff	
St. Louis Grand Prize	Smooth	Red	Brown	Yellow	3.5	July 9		
					1913			
Reliable	....	....	....	....	3.7	July 6		
Acme Bred "a"	Bearded	Red	Brown	Purple	4.3	July 5	Fairly stiff	
Acme Bred "b"	Bearded	Red	Brown	Yellow	3.3	July 7	Fairly stiff	
Klondyke	Smooth	White	Brown	Yellow	4.1	July 8	Stiff	
Miracle	Bearded	Red	White	Purple	4.0	July 5	Rather weak	

Varieties Discontinued Since 1907

Name	Years grown	Why discontinued
R. New Yorker	1901-1909	Did not give good average yields.
Funk's Turkey Red	1908-1909	Gave very low yields. Plainly not adapted to Eastern conditions, though the most important wheat of Middle West.
Martin Amber	1901-1909	Yielded fairly well.
R. New Yorker No. 57	1901-1909	Did not give good average yield.
Wheat No. 1	1903-1909	Discontinued because it was not known just what varieties they are.
Wheat No. 2	1899-1908	
Wheat No. 3	1903-1908	
Harvest Queen	1899-1909	Average yield was low.
Spring	1908-1910	Yields were very low.

Sources of Seed Secured During Years 1907-1912

1 Acme Bred, S. M. Schindel, Hagerstown, Md., succeeded by Scott and Matthews.

2 Councilman, Maryland Experiment Station.

3 Currell's Prolific, Maryland Experiment Station.

4 Eclipse, Maryland Experiment Station.

5 Four-rowed Fultz, Hoffman Homestead Farm, Bamford, Lancaster County, Pa.

6 Fultzo-Mediterranean, Maryland Experiment Station.

7 "Glace," H. M. Glace, Shickshinny, Pa., R. F. D. 1.

8 Gypsy, Ohio Experiment Station.

9. Klondyke, Hoffman Homestead Farm.

10 Lancaster Fulcaster, Hoffman Homestead Farm.

11 Mealy, Ohio Experiment Station.

12 Miracle, W. J. Massey, Prices, Md.

13 Nigger, Ohio Experiment Station.

14 Poole, Ohio Experiment Station.

15 Red Wave, Hoffman Homestead Farm.

16 St. Louis Grand Prize, Hoffman Homestead Farm.

17 Wyandotte Red, Maryland Experiment Station.

The Best Varieties

The results secured in these trials are of more value to farmers who have Hagerstown soil than to those who have quite different soil. Without actually trying the varieties under other sets of conditions, one could only guess at their relative merits and so it is possible only to recommend for trial the varieties which have done well at the Experiment Station. In the tables giving the average yields, the varieties are given in order of yield, the highest first.

Dawson's Golden Chaff, which has outyielded all other varieties, is a white wheat of inferior milling qualities, and this should be taken into account by those who contemplate growing it. All the other varieties which have yielded well have red grains, except Jones' Longberry No. 1, and would command a better price in the market.

Considering the average yields in both tables, the following varieties can be most highly recommended for yield, though the order in which the varieties are given is not necessarily that of merit:

Dawson's Golden Chaff.
China.
Fulcaster.
Harvest King.
Jones' Longberry No. 1.
Turkish Amber.
Currell's Prolific.
Ontario Wonder.

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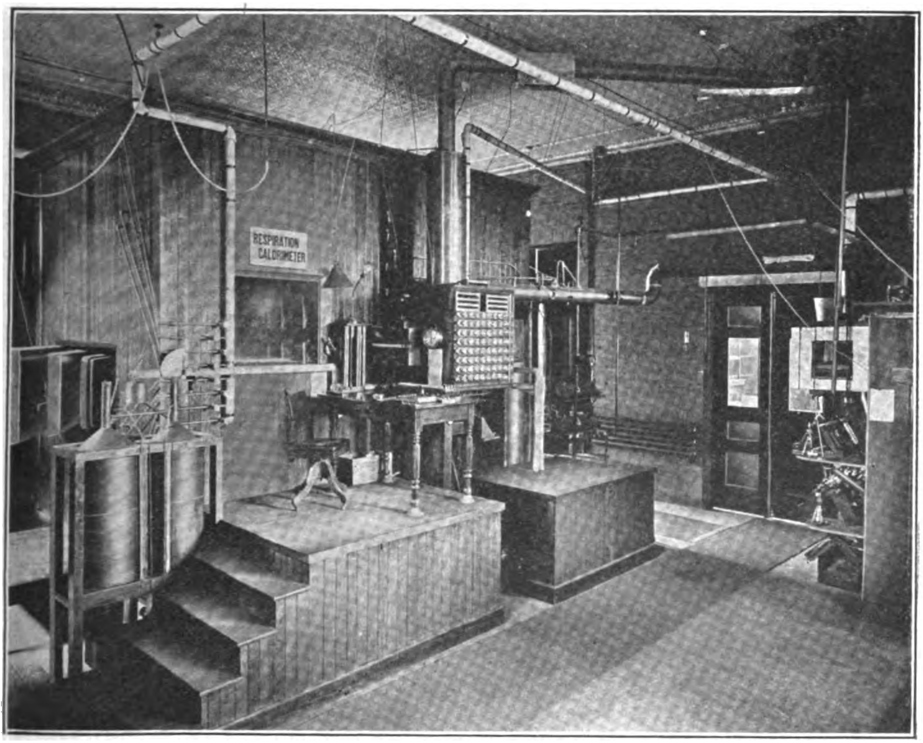
The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 126



FOOD AS BODY FUEL

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CENTRE COUNTY, PENNSYLVANIA
NOVEMBER, 1913.

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*Absent on leave.

Sun Ptg. & Bdg. Co., Williamsport, Pa.

The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 126

FOOD AS BODY FUEL*

By HENRY PRENTISS ARMSBY
Director of the Institute of Animal Nutrition

In 1898 the United States Department of Agriculture proposed to The Pennsylvania Experiment Station that it undertake in cooperation with the Bureau of Animal Industry a series of investigations into the fundamental scientific principles of animal nutrition. The Department's proposition was accepted by the Trustees and after a study of the chief types of American and foreign apparatus, the construction of a respiration calorimeter modelled after the one devised by Atwater & Rosa at Middletown, Conn., for experiments upon man was begun. This apparatus was completed and the first series of experiments made in 1902, it being the first apparatus of the sort for experiments on domestic animals. When the agricultural work of the College was reorganized in 1907, this line of investigation had assumed so much importance that it was constituted a separate department, independent of the School of Agriculture and Experiment Station, although affiliated with it, under the name of the Institute of Animal Nutrition.

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*Investigations under the Adams Act in cooperation with the Institute of Animal Nutrition and the Bureau of Animal Industry of the United States Department of Agriculture.

The investigations which the Institute of Animal Nutrition is conducting constitute a study of the fundamental principles of animal nutrition from that standpoint which regards the food of man or animals as the source of energy to the body.

The Animal a Prime Motor

The living animal constitutes what the engineer calls a *prime motor*, that is, it generates power for its own operation and is able to produce a surplus which may be used to do work of one sort or another. In particular there is a very close resemblance between the animal body and the various forms of internal combustion motors (oil, gas, gasoline, etc.,) which have become so familiar in recent years. Both are mechanisms designed to utilize the chemical energy stored up in fuel of one sort or another for the performance of work and the requirements of both are similar. To keep a device used for this purpose in running order repair material is necessary—steel, brass, etc., for the engine, proteins and mineral matters for the animal—but in both cases the chief demand is for fuel material.

Transformations of Energy

When fuel is burned in the cylinder of the engine the energy which it contains is transformed, part appearing as work but usually considerably more taking the form of heat, while if the engine is run without load, all the energy of the fuel used is changed into heat, in part directly in the cylinder and in part through the heating of the bearings by friction. Such an engine is spoken of as a transformer of energy because it changes one form of energy into another. The case of the animal body is precisely similar. The materials digested from its food are carried by the blood to the working tissues and there virtually burned. Part of their energy may be used to do visible external work, but even then much of it is converted into the form of heat, while in the animal in a state of so-called rest, the work done by the internal organs finally results in the generation of heat, somewhat as does the motion of the unloaded engine.

Food as Fuel

The food, then, may be regarded in the light of fuel for the bodily mechanism, and may be studied from this point of view.

With the aid of the elaborate apparatus, already mentioned, the Institute of Animal Nutrition is engaged in investigating the values of different feeding stuffs as sources of energy for the animal, seeking to determine the efficiency with which their energy can be used by different animals and under various external conditions. Similar investigations have been carried on elsewhere, notably by Kellner in Germany, and methods of comparing feeding stuffs and computing rations have been based upon the results.

Comparison with Engine

A fundamental question which at once arises, however, is whether we are really justified in comparing the burning of gasoline in an engine with the combustion of food materials in the body. In the one case the fuel is burned suddenly and almost or quite completely at a high temperature. In the body, the oxidations take place rather slowly, at a comparatively low temperature, and through many intermediate stages, and yield considerable amounts of incompletely burned products. Morever, the animal machine is a *living* machine and we are not justified in assuming in advance of the evidence that energy is transformed in the living being in the same manner and according to the same laws as in lifeless matter.

The Conservation of Energy

In the case of the latter, it has been found in a great number of exact investigations that whenever one form of energy disappears an equivalent amount appears in some other form. Thus, if heat is produced by mechanical means, such as the fall of a body from a height, friction, or other means, the heat which appears is always exactly proportional to the mechanical energy used up in producing it. If the stored up energy of gasoline is used to run an engine, the work done plus the heat produced always bears the same relation to the energy contained in the gasoline burned. This universal experience is expressed in the *law of the conservation of energy*, which asserts in substance that energy is indestructible. It may change its form, but its total amount is neither increased nor diminished. Is this law true of the animal motor? Does the combustion of its feed set free the same amount of energy in the body as if it were burned as fuel to operate an engine? If it does, then, if we were to measure on the one hand the work plus the heat produced by an animal, or more simply still if we were to experiment on an animal doing no work and measure its heat production, the latter should be equal to the heat which would be produced by burning the same materials outside the body. In other words, the question just raised may be substantially answered by experiments upon the origin of animal heat.

Origin of Animal Heat

Every one knows that animals produce heat, but only in comparatively recent years has the origin of that heat been fully demonstrated. To the ancients it was entirely a mystery. They located it in the heart and their attempted explanations of its source were simply verbal. Galen, for example, speaks of it as "That heat which is innate in the heart, which was placed there as the source of the heat of the body by God in the beginning of life and which remains there until death."

Not until oxygen was discovered almost simultaneously in 1774 by Priestly in this country and by Scheele in Sweden, and until the investigations of Lavoisier had demonstrated its relations to combustion, was a rational understanding of the origin of animal heat possible. In 1777 Lavoisier showed that the oxygen of the air taken into the lungs in respiration serves to maintain a process of slow combustion in the body. This he regarded as the source of the animal heat and a little later he succeeded in measuring the heat produced by a guinea pig and found its amount to correspond approximately to that to be expected from the amount of material burned in the body.

This view of the matter, however, was far from being accepted by Lavoisier's contemporaries and even yet there is often a feeling that "animal heat" is somehow different from other heat—that for example the removal of the animal heat from milk is something different from simple cooling—but still it has come to be generally recognized that the heat which every living animal produces has its origin in the burning within the body of the materials supplied by the food. The temperature of a tight stable is kept above that of the outer air by the combustion in the bodies of the animals of the nutrients digested from the hay and grain which they consume. In the further development of this idea, feeding stuffs have now come to be regarded largely in the light of fuel for the animal machine, supplying energy for its motions and, more or less incidentally, heat to keep it warm, while any surplus food is stored up in the form of fat as a reserve of fuel material against future needs.

Computed and Observed Heat Production

As just stated, Lavoisier believed that he had shown that the combustions in the body accounted for the heat produced. This novel view led to a number of experiments by subsequent investigators who failed to obtain as good an agreement as did Lavoisier. We now know of numerous sources of error in these experiments as well as in Lavoisier's, however, so that they are of little value as evidence. Only within the last twenty years has the development of scientific methods rendered possible really accurate investigations of this question. Within that time several investigators have taken it up by substantially the method just outlined, *i. e.*, they have compared the heat actually produced by an animal with that which would be produced by the burning of the same materials outside the body.

Experiments on Dogs

The first investigation of this sort was made by Rubner in Germany in 1894 on two dogs. In the aggregate of experiments covering 45 days, the actual heat production as determined by Rubner's form of animal calorimeter agreed closely with the amount computed from the body oxidations, as the following comparison shows. The small difference of one-third of one per cent is quite within the limits of unavoidable error in such experiments.

Computed heat production..............	17406.0	Cals.*	
Observed heat production..............	17349.7	"	
Difference	—56.3	"	=—0.32%

About four years later Laulanié in France reported similar comparisons on several different species, by what appear to have been somewhat less rigorous methods, which likewise showed a close agreement, the observed differing from the computed heat production in the aggregate of all the experiments reported in full by—0.31%.

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*A calorie (abbreviation, Cal.) is the amount of heat required to raise the temperature of one kilogram of water 1°C. or that of one pound of water about 4°F. For all the purpose of this bulletin, however, it is sufficient to regard it as the unit used in measuring heat, just as a yard is a unit of length.

Experiments on Men

The most extensive investigations of this sort are those made in this country by Atwater, Benedict and their associates upon men. In a number of these experiments the subject did considerable mechanical work which was converted into heat inside the apparatus. In 30 experiments reported up to the year 1902 and covering 93 days, the total observed and computed heat production and the percentage difference were:

Computed heat production	249063	Cals.	
Observed heat production	248930	"	
Difference	—133	"	=—0.05%

Benedict & Milner in 11 later experiments, aggregating 24 days, with an improved form of apparatus, obtained the following results:

Computed heat production	95075	Cals.	
Observed heat production	95689	"	
Difference	+614	"	=+0.65%

Still later Benedict reported 18 experiments upon men, covering in all 53 days, which gave the following results:

Computed heat production	102078	Cals.	
Observed heat production	101336	"	
Difference	— 742	"	=—0.73%

Few Results on Herbivora

These results show beyond reasonable doubt that the animal heat produced in dogs and in man is exactly accounted for by the amounts of food and body material burned during the same time. The experiments, however, with the exception of a few of Laulanié's, did not include herbivorous animals, the class to which the more important farm animals belong. For various reasons, therefore, direct investigations upon these animals, and in particular upon ruminants, appear desirable. Not only do these animals differ as regards their digestive and other processes from carnivorous animals and from man, but in particular the newer method of comparing the nutritive values of feeding stuffs for farm animals which has been introduced by Kellner—his "starch values" which are really energy values—practically assumes that energy is utilized in the animal body in accordance with the same general laws as elsewhere.

Experiments on Cattle

The investigations begun here in 1902 afford data upon this point. The experiments have been upon mature or nearly mature cattle. In each of them the quantities and kinds of material burned in the body were ascertained by comparing the amounts of the different chemical elements contained in the feed with those found in the excreta, including especially the gases given off by the animal, which were determined by means of the respiration calorimeter. This same apparatus permits the exact determination at the same time of the amount of heat produced by the animal, which can then be compared with that computed from the materials oxidized. The results of 57 such experiments of 2 days each on 7 different animals, including all which had been completed and computed up to the close of the year 1909, are given in the table appended to this bulletin. A reference to that table shows that while the results of individual trials differ more or less, sometimes the computed heat production and sometimes the observed being slightly the greater, the differences are in both directions and in the aggregate a very close agreement is found, the total figures being:

Computed heat production	976204	Cals.	
Observed heat production	980234	"	
Difference	+4030	"	=+0.41%

If the unsatisfactory results of the year 1905 be omitted, the discrepancy is reduced to —0.07%.

These results may be taken as demonstrating that the conversion of the energy of the feeding stuffs of our farm animals into heat and work is governed by the same general laws which apply to other classes of animals and to the transformations of energy in lifeless matter. The results, therefore, fully justify basing comparisons of the values of feeds upon their content of energy in forms available to the animal organism.

Summary of all Experiments

Finally, it is of interest to sum up the results, of all the reported experiments upon this subject, as has been done in the following table which shows the total computed and observed heat production of all these experiments taken together. The difference between the two is one-quarter of one per cent, or quite within the limits of accuracy of experimental methods of this sort.

Experimenter.	Total number of days	Total computed heat production Cals.	Total observed heat production Cals.	Percentage difference
Rubner	45	17406	17350	— 0.32
Laulanié	7	1865	1859	— 0.31
Atwater & Benedict	93	249063	248930	— 0.05
Benedict & Milner	24	95075	95689	+ 0.65
Benedict	53	102078	101336	— 0.73
Armsby & Fries	114	976204	980234	+ 0.41
	336	1441691	1445398	+ 0.26

Conclusions

These results may be taken as demonstrating that the animal heat arises exclusively from the combustions in the body, but they have a much broader significance. They show that the transformations of chemical energy into heat and work in the animal body take place according to the same general laws and with the same equivalencies as in our artificial motors and in lifeless matter generally. The great law of the conservation of energy rules in the animal mechanism, whether in man, carnivora or herbivora, just as in the engine. The body neither manufactures nor destroys energy. All that it gives out it gets from its food and all that is supplied in its food is sooner or later recovered in some form. We are fully justified, therefore, in speaking of the food as body fuel, and in our studies of its utilization we may be confident that any food energy which does not reappear in the form of heat or work has not been lost but has been stored up in the body as the chemical energy of meat, fat, etc., which may later serve to supply food energy to the human body when consumed as food by man.

Observed and Computed Heat Production of Cattle.

48-hour Experiments.

	Gain by animal Cals.	Heat Production		Difference	
		Computed Cals.	Observed Cals.	Cals.	Per cent.
Steer I 1902	— 5482	18486	18430	— 56	—0.3
	— 1614	20402	20592	+ 190	+0.9
	— 18	22232	21498	— 734	—3.4
	+ 1048	23154	22986	— 168	—0.7
Steer I 1903	— 6818	23270	23058	— 212	—0.9
	— 8358	20246	20246	0	0
	— 5036	21310	21080	— 230	—1.1
	+ 7582	28362	29304	+ 942	+3.2
Steer I 1904	—10486	22028	21822	— 206	—0.9
	—10748	22370	23472	+1102	+4.7
	— 2678	23960	22870	—1090	—4.8
	— 2172	23454	22636	— 818	—3.6
	— 5430	22548	21448	—1100	—5.1
	— 5540	22132	21750	— 382	—1.8
Steer A 1905	— 2520	16094	17212	+1118	+6.5
	+ 2234	17652	18298	+ 646	+3.5
	— 4878	11958	12392	+ 434	+3.5
	— 2542	14570	14712	+ 142	+1.0
Steer B 1905	— 1636	12758	13242	+ 484	+3.6
	+ 1658	13802	14654	+ 852	+5.8
	— 3788	9650	10442	+ 792	+7.6
	— 1070	10692	10868	+ 176	+1.6
Steer A 1906	+ 2736	18498	18678	+ 180	+1.0
	+ 8610	25764	25744	— 20	—0.1
	— 5020	14690	14904	+ 214	+1.4
	— 574	16330	16418	+ 88	+0.5
Steer B 1906	— 1280	18106	17874	— 232	—1.3
	+ 2266	19400	19472	+ 72	+0.4
	— 4094	13418	13856	+ 438	+3.2
	— 876	14896	14760	— 136	—0.9
Steer A 1907	+ 3398	20480	20348	— 132	—0.6
	+12682	28180	28280	+ 100	+0.4
	— 3310	15532	15546	+ 14	+0.1
	+ 1256	18814	18986	+ 172	+0.9
Steer B 1907	— 332	18980	19072	+ 92	+0.5
	+ 5146	22660	23042	+ 382	+1.7
	— 4566	15706	15790	+ 84	+0.5
	+ 326	18330	18856	+ 526	+2.8
Steer D 1908	- 2554	10138	10058	— 80	—0.8
	-- 3846	8156	8042	— 114	—1.4

Observed and Computed Heat Production of Cattle—Cont.

48-hour Experiments.

	Gain by animal	Heat Production		Difference	
	Cals.	Computed Cals.	Observed Cals.	Cals.	Per cent.
Steer E 1908	+ 1630	14300	14174	— 126	—0.9
	— 1724	11106	11048	— 58	—0.5
	— 3908	10016	9806	— 210	—2.1
	+ 1456	14874	15374	+ 500	+3.2
	— 2880	11328	11390	+ 62	+0.5
	— 3926	9046	9292	+ 246	+2.6
Steer C 1908	— 3910	14338	14092	— 246	—1.7
	— 4218	12210	11890	— 320	—2.6
	— 1690	18354	17950	— 404	—2.3
	— 2928	14132	14230	+ 98	+0.7
	— 4000	11768	11868	+ 100	+0.8
Steer F 1909	+ 4294	17512	17978	+ 466	+2.6
	— 190	14738	14808	+ 70	+0.5
	— 3872	12620	12686	+ 66	+0.5
	+ 1000	21568	22012	+ 444	+2.0
	— 2372	15394	15462	+ 68	+0.3
	— 6296	13692	13436	— 256	—1.9
Totals and averages 57 experiments. . .	—91808	976204	980234	+4030	+0.4
49 experiments omitting those of 1905. . .	—79316	869028	868414	— 614	—0.07

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The Pennsylvania State College Agricultural Experiment Station

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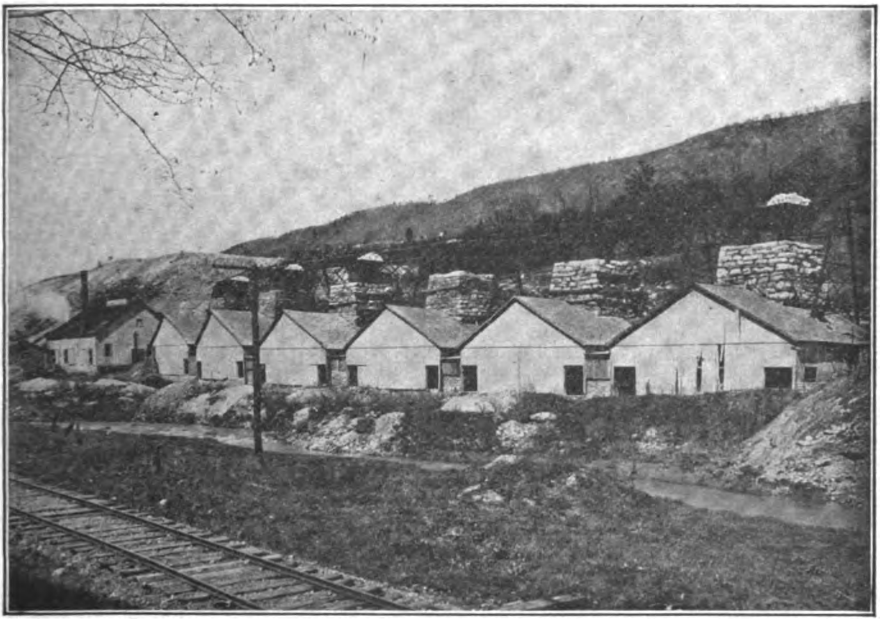

MODERN LIME KILNS

PENNSYLVANIA LIMESTONE AND LIME SUPPLIES

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DECEMBER, 1913.

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BULLETIN No. 127

PENNSYLVANIA LIMESTONE AND LIME SUPPLIES

BY WILLIAM FREAR

Owing to the renewed interest in the agricultural use of limestone and lime, especially for the neutralization of acid soils, with the aim of improving conditions for the culture of clover and alfalfa, the Station is frequently asked concerning the composition of limestone deposits in various parts of the State, their fitness for crushing and burning, and the places where such materials may be purchased prepared for application.

In the Annual Report of the Station for 1911-12, the writer with Mr. E. S. Erb, Assistant Chemist, has presented the existing data concerning the compositions of the limestones derived from the several, numerous limestone formations of Pennsylvania, arranged in relation to their geological formations. Inasmuch as the limited edition of the Annual Report makes impossible its distribution to the general mailing list of the Station, a very condensed compilation of the analyses given in the report, together with others of more recent date, has been prepared.

Limestones

Pennsylvania, with her great range of geological formations, has numerous beds of limestones, of which not less than fifty-four are sufficiently definite to have received distinguishing names. There are few counties of the State that are entirely lacking in limestone formations, though in the extreme southeast, along the northern border, and in the northwest, the limestones exposed are rarely suitable for development. In the following table, the several distinct limestone formations are listed in their geological order, beginning with those of most recent age, with a very brief indication of the associated strata serving to identify them. Among the coal measures the several limestone beds are usually located a short distance *below* the corresponding coal-beds; but, for convenience of expression, the list gives the formations immediately below the several limestone formations named. A full conception of the related strata can be had only by considering the several strata lying above, as well as those lying below any particular limestone.

Pennsylvania Limestones and Their Geological Relations.

(From the More Recent to the Older Geological Periods.)

Note: Formations marked * are quarried in many localities; those marked † in restricted localities. Those not marked are of no known present economic value.

Mesozoic Time: † Mesozoic Limestone (York County).

Palaeozoic Time:

Carboniferous System.

1. Permian Group (Upper Barren Measures).	**Dunkard Series** XVII. Greene County Division (Series).	Limestones XI-XIV.—Above Nineveh coal.
		Limestone X.—Above Fish Creek sandstone and Dunkard coal.
		Limestone VII-IX.
	XVI. Washington County Division (Series).	†Limestone VI.—Upper Washington limestone. Separated from VII by shale; overlying sandstone.
		Limestone V.—Jollytown limestone; overlying Jollytown coal.
		Limestone IV.—Middle Washington limestone; overlying sandstone and shale.
		Limestone III.—Overlying shale and sandstone.
		Limestone II.—Lower Washington limestone: Overlying Washington coal, sandstone and Little Washington coal.
		Limestone Ib.—Taylortown Limestone: Overlying Waynesburg B (Taylortown) coal.
		Limestone Ia.—Colvin's Run limestone: Overlying Waynesburg A (Zollersville) coal.
		†Martinsburg Limestone: Overlying Waynesburg sandstone.

- **2. Pennsylvania Group**
  - **a. XV. Monongahela (Upper Productive) Measures.**
    - **Waynesburg Limestone: Underlying Waynesburg coal and overlying Uniontown coal.**
    - *Benwood (Great) Limestone:
      - Upper or Uniontown Division
      - Sandstones or shales
      - Lower Division.
      - **Overlying Sewickley coal.**
    - ***Fishpot (Sewickley) Limestone.**
    - ***Redstone Limestone: Overlying Pittsburgh coal.**
  - **b. XIV. Conemaugh (Pittsburgh) Series. (Lower Barren Measures).**
    - ***Pittsburgh Limestone: Overlying Little Pittsburgh coal.**
    - Little Pittsburgh Limestone: Overlying Connellsville and Morgantown sandstones, and Elk Lick coal.
    - †Elk Lick Limestone.
    - Ames (Green Ferriferous) Limestone.
    - Crinoidal Limestone: Overlying Platt coal.
    - Black Ferriferous Limestone: Overlying Price (Bakerstown) and Coleman coals.
    - †Pine Creek (Coleman) Limestone: Overlying Philson coal.
    - †Brush Creek (Philson) Limestone: Overlying Brush Creek (Masontown) coal and Mahoning sandstone.
  - **c. XIII. Allegheny Series or Lower Productive Measures.**
    - *Freeport Upper Limestone: Under Freeport Upper coal, ("E") and over Freeport Lower coal ("D").
    - *Freeport Lower Limestone: Over Freeport sandstone and Kittanning Upper coal ("C").
    - *Johnstown Limestone (Cement Bed): Over Johnstown Upper ("C") and Lower ("B") coals, Kittanning sandstone and Buhrstone iron ore.
    - *Vanport (Ferriferous) Limestone: Overlying Clarion ("A") and Brookville ("A") Coals.
  - **d. XII. Pottsville Conglomerate.**
    - Mercer Upper Limestone.
    - Mercer Lower Limestone.
    - **Mercer, Lawrence, Beaver Counties.**

3. Mississippi Group.	a. XI. Mauch Chunk Shale.	†Greenbrier (Mountain) Limestone; (In lower part of the formation).	
	b. X-XI.	†Loyalhanna (Siliceous) Limestone: (Between formations X and XI, or near the base of the latter).	
	c. X. Pocono Sandstone.	Meadville Upper Limestone Meadville Lower Limestone Cussewago Limestone.....	Crawford County.
		Marion Creek Limestone: McKean County.	
		†Benezette Limestone: Elk County.	

Devonian System.

IX.	Catskill Formation (Catskill or Old Red Sandstone).	†Cherry Creek or Catskill Limestone: Wayne and Susquehanna Counties.
VIII.	Chemung Formation (Chemung Shales and Sandstones).	Great Bend Limestone: Susquehanna County. †Burlington Limestone: Bradford County. Erie Limestone: Erie County.
	Next below the Chemung, occur the Portage Beds (sandstones and shales), Genessee Shale (Black Slates), and in the New York horizons, but not in Pennsylvania, Tully Limestone.	
	Hamilton Shale: (Sandstone and Shales).	Encrinal Limestone: Under Moscow Shale in the upper division of three constituting this formation.
	Marcellus Shale: (Black Shales).	
	†Onondaga: (Upper Helderburg or Corniferous Limestone).	
VII	Oriskany Formation: (Sandstone).	
VI	Helderbergian (Lower Helderberg Series).	Stormsville Limestone (with shales). Decker's Ferry Magnesian Limestone. *Lewistown (Bossardville) Limestone. Poxono Island Limestone (with shales). Water-Lime Beds.

Silurian System.

V.	Cobleskill Limestone:	†Lewisburg Limestone.
	Niagara Limestone.	
	Salina Beds (Shale).	In New York regions; possibly represented in Pennsylvania by † Barree Limestone (Huntingdon County).
	Clinton Shales.	Sometimes enriching to limestones (†Lewisburg and Lime Ridge).
	Tuscarora (Medina) Sandstone.	Belongs to Formation IV, in Pennsylvania Survey Classification.

Ordovician System.

IV.	Juniata Shale and Sandstone:	Bald Eagle, Eden, etc., formations (Oneida slate).
III.	Richmond and Lorraine Beds (Hudson River Shales) and Utica Shale.	
II.	*Trenton Limestone.	
	*Black River Limestone.	
	*Stone's River (Chazy) Limestone.	
	*Beekmantown (Calciferous) Limestone.	

Cambrian System.

I.	Potsdam (Sandstone) Saratoga, Acadian and Georgian Series.

Archean System.

Huronian Series (†with isolated marble beds) and Laurentian Series.

For guidance in studying the tables of analyses, the following facts are noted:

For soil amendment, the limestone must be reduced to a fine powder, by either mechanical or chemical means. Present information indicates that the fineness of the crushed limestone should be at least 1-60 of an inch in diameter, if economical, immediate return is desired. Large and complex crushing apparatus is required for this purpose. In mixtures of coarse and fine particles, produced by simpler apparatus, only the fine particles are of immediate value.

For neutralizing sour soils, the carbonates of lime and magnesia are practically the only valuable constituents of a limestone.

The magnesium carbonate probably reacts somewhat more slowly than lime with the soil, but there sets up changes quite similar to those caused by lime. Some investigators who have found injurious effects from the action of magnesium salts, chiefly from studies with plants grown in dilute solutions of nutritive salts, incline to advise against the use of magnesian limestone for soil amendment; but the conditions of field use are so different from those in which the injurious effect was observed, and the favorable experience with magnesian limestone so general and long continued in Pennsylvania farm practice, that the writer has not been convinced that, in localities where good magnesian limestones and limes are much the cheaper, it is advantageous to look afar and pay a higher price for non-magnesian limestone or lime.

It may be added that magnesian limestones burn more easily than purely calcareous limestones, but slake more slowly, with less manifestation of heat, with less swelling and sometimes with unsatisfactory pulverization; but that even highly magnesian lime commonly slakes fine, if abundance of water be used in the slaking.

The tables of analyses contain statements of the location represented, the related geological formation, where that is definitely ascertained, and such information concerning the burning quality as has been obtained from the Station's tests and other sources. The tables are arranged by counties.

The sources of the several analyses are briefly indicated by Roman numerals, as follows: I. From the analytical records of the Experiment Station Laboratory (Department of Experimental Agricultural Chemistry); II. Publications of the Second Geological Survey of Pennsylvania. III. Publications of the U. S. Geological Survey. IV. Analyses by the Chemical Department of The Pennsylvania State College. V. From private sources.

Analyses of Pennsylvania Limestones, by Counties.

LOCATION AND OWNER.	Source of Analyses	Geological Formation	COMPOSITION (PER CENT.)							Burning Tests
			Calcium Carbonate	Magnesium Carbonate	Iron and Aluminum Oxids	Sand, clay, etc. (Insoluble)	Other minerals	Undetermined.	Total	
ADAMS COUNTY (See York County)										
ALLEGHENY COUNTY.										
Federal (S)	I		32.45	23.48	6.20	31.10	4.62	2.15	100.00	
ARMSTRONG COUNTY.										
Apollo: Apollo Lime & Ballast Co.	III	Vanport	95.13*	1.47*	2.75	1.75	....	....	101.50	
Apollo: Apollo Lime & Ballast Co.	III	Vanport	95.68*	.55*	2.37	.73	....	.67	100.00	
Apollo: Apollo Lime & Ballast Co.	III	Vanport	93.16*	1.34*	1.66	2.93	....	.91	100.00	
Belknap: H. L. Ellenberger	I	Johnstown,	55.00	Traces	2.20	42.07	....	.73	100.00	
Cochran's Mills (1 m. S. E.): M. Davis	II	Johnstown	53.75	9.99	7.73	23.84	.27	4.42	100.00	
Dayton (½ m. E.): W. Marshall	II	Freep't Up.	94.98	1.21	1.25	1.92	.04	.65	100.00	
Greendale (E. of): Rhee	II	Vanport	93.25	1.74	1.67	3.42	.07	....	100.15	
Kittanning (½ m. N.): Rose Reynolds	II	Vanport	95.57	1.42	.93	2.11	.07	....	100.10	
Logansport: Mahaffey & McGill; Up. layer	II	Freep't Up.	96.45	1.44	.96	.83	.01	.31	100.00	
Logansport: Mahaffey & McGill; 4th layer	II	Freep't Up.	93.21	2.06	1.34	2.20	.01	1.18	100.00	
Logansport: Mahaffey & McGill; 6th layer	II	Freep't Up.	93.57	1.32	1.21	3.17	.06	.67	100.00	
Mahoning Furnace, (¼ m. N. W.): Colwell	II	Vanport	94.72	1.04	1.38	2.30	.10	.46	100.00	
Manorville: Dull & Co.; 3rd bench	II	Freep't Up.	89.30	1.90	2.00	4.83	.04	1.93	100.00	
Manorville: Dull & Co.; 5th bench	II	Freep't Up.	82.59	5.75	3.37	7.31	.13	.85	100.00	
Manorville: Dull & Co.; 6th bench	II	Freep't Up.	89.86	2.90	1.86	4.52	.03	.83	100.00	
Pine Creek Furnace	II	Vanport	96.78	1.28	1.00	.37	.21	.38	100.00	
Putneyville: G. S. Putney	II	Johnstown	64.16	1.84	7.45	22.28	.64	3.63	100.00	
Putneyville (1½ m. N.): W. R. Hamilton	II	Freep't Up.	84.86	1.87	2.57	9.52	.05	1.13	100.00	
Rural Valley: J. Riefer	II	Freep't Up.	88.84	1.51	2.56	5.03	.04	2.02	100.00	
Slate Lick (2 m. S. W.) S. Monroe	II	Freep't Up.	94.64	1.57	1.18	1.85	.02	.74	100.00	
South Bend: Near Mr. George's	II	Vanport	94.18	1.48	2.09	2.10	.06	.09	100.00	
Stewardson Furnace	II	Vanport	96.01	1.50	7.46	.79	.07	.17	100.00	
BEAVER COUNTY.										
Vanport: Power; upper bench	II	Vanport	88.46	1.44	2.32	7.03	.30	.45	100.00	
" Power; middle bench	II	Vanport	91.61	1.57	1.29	4.78	.79	....	100.04	
" (½m.S.W.): Severn; upper bench	II	Vanport	93.48	1.54	1.82	2.77	.17	.22	100.00	
" (½m.S.W.): Tygert; lower bench	II	Vanport	91.09	1.59	1.59	4.80	.20	.73	100.00	

Analyses of Pennsylvania Limestones, by Counties—(Cont.)

LOCATION AND OWNER.	Source of Analyses	Geological Formation	COMPOSITION (PER CENT.)							Burning Tests
			Calcium Carbonate	Magnesium Carbonate	Iron and Aluminum Oxids	Sand, clay, etc. (Insoluble)	Other minerals	Undetermined.	Total	
BEDFORD COUNTY.										
Koontzville: Koontz Quarry	II	Ordovician	90.60	1.90	.60	6.41	.06	.43	100.00	
Woodbury: (¾ m. N.) J. R. Stayer	I	Ordovician	56.39	31.97	2.06	7.78	....	1.80	100.00	Lime, white; slakes slowly to powder; swells ¼ volume.
Woodbury: (1 m. N. N. E.), J. R. Stayer	I	Ordovician	55.36	40.12	.68	3.70	....	.14	100.00	Lime, white; slakes rather slowly to fairly fine powder; swells ¼ volume.
BERKS COUNTY:										
Bechtelsville: M. G. Oberholtzer	I	Ordovician	54.24	43.96	.90	.85	....	....	100.15	
Blandon: John Reeser	III	Ordovician	91.53	2.39	1.86	4.03	....	.19	100.00	
Caernarvon Twp.: D. Hubert Plank	I	Ordovician	73.70	20.10	.51	2.10	....	3.39	100.00	
Caernarvon Twp.: D. Hubert Plank	I	Ordovician	63.53	30.26	1.52	2.77	....	1.92	100.00	
Caernarvon Twp.. D. Hubert Plank	I	Ordovician	94.50	....	....	....	....	5.50	100.00	
Caernarvon Twp. D. Hubert Plank	I	Ordovician	75.50	19.50	.90	3.80	....	.80	100.00	
Esterly: Dr. S. Brumbach	I	Ordovician	49,30	25.88	2.58	20.89	....	1.26	100.00	
Esterly: Dr. S. Brumbach	I	Ordovician	56.80	38.11	.91	4.61	....	....	100.42	
Esterly: Dr. S. Brumbach	I	Ordovician	48.67	29.55	1.55	16.90	....	3.33	100.00	
Kutztown: Sell D. Kutz	III	Ordovician	89.54	3.02	1.55	3.90	....	1.99	100.00	
Kutztown: Sell D Kutz	III	Ordovician	88.00	6.00	....	4.00	....	2.00	100.00	
Kutztown: Sell D. Kutz	III	Ordovician	90.00	4.00	....	3.00	....	3.00	100.00	
Mertztown: T. L. Trexler	III	Ordovician	92.78	2.22	1.80	3.20	....	....	100.00	
Morgantown: H. Hertzler	I	Ordovician	54.64	44.65	.74	.85	....	....	100.88	
Robesonia: S. R. Deppau	IV	Ordovician	94.40	....	1.44	....	....	4.14	100.00	
Temple: Reading Quarry Co	III	Ordovician	55.50	43.00	1.10	.40	....	....	100.00	
Womelsdorf: Valentine, old quarry	I	Ordovician	59.32	32.01	2.86	4.98	....	.83	100.00	Lime, nearly white; slakes fine readily; swell ¾.
Womelsdorf: Valentine, old quarry	I	Ordovician	72.69	19.47	1.68	6.08	....	.08	100.00	Lime, white to gray white; slakes well; swell ¾.
Womelsdorf: Valentine, new quarry, stone gray and pink	I	Ordovician	62.71	25.26	2.10	9.56	....	.37	100.00	Lime, yellow white; slakes slowly; swell ½.
Womelsdorf: Valentine, new quarry, stone light gray	I	Ordovician	59.96	29.48	2.54	8.26	....	....	100.24	Lime grayish white; slakes slowly; swell, double.
Womelsdorf: Valentine, new quarry, stone, black	I	Ordovician	91.08	5.33	.90	3.14	....	....	100.45	Lime, white; slakes quickly; swell, double.

*Recalculated.

† Aluminum oxid only.

BERKS COUNTY (Cont.)										
Womelsdorf: Valentine, new quarry, stone, dark blue	I	Ordovician	52.14	7.98	4.26	35.86	....	....	100.24	Lime, mixed white and gray; white part only slakes slowly; swell, very slight.
BLAIR COUNTY.										
Altoona: Baker's Ore Mine, upper layer	II	Lewistown	95.66	1.55	.84	2.50	.29	....	100.84	
Altoona: Baker's Ore Mine, middle layer	II	Lewistown	95.09	1.58	.64	3.00	.12	....	100.43	
Altoona: Baker's Ore Mine, lower layer	II	Lewistown	95.57	1.52	.57	3.02	.09	....	100.77	
Bald Eagle	I	Lewistown	97.00	1.51	.80	2.85	....	....	102.16	
Birmingham: Borie	II	Ordovician	48.03	37.67	2.85	10.38	1.26	....	100.09	
Keystone Lime Co	II	Ordovician	53.87	41.32	1.19	29.10	.14	.13	?	
Duncansville: E. E. McGill	I	Lewistown	93.54	1.59	.68	4.06	....	....	100.00	
Franklin Forge: St. Clair Limestone Co	III		91.07[*]	5.04[*]	1.10	4.20	....	....	101.41	
Franklin Forge: St. Clair Limestone Co	III		94.00	3.00	....	2.00	....	1.00	100.00	
Frankstown: American Lime & Stone Co	III	Lewistown	98.04[*]	....	1.00	1.06	....	....	100.10	
Frankstown: American Lime & Stone Co	I	Lewistown	94.48	2.57	1.60	1.40	....	....	100.05	
Frankstown: American Lime & Stone Co	I	Lewistown	92.90	2.88	2.60	1.60	....	.02	100.00	
Hollidaysburg: Cressnell quarry	II	Lewistown	95.25	2.26	.05[†]	1.80	.88	....	100.24	
Hollidaysburg: Loop property	II	Lewistown	84.78	3.86	.04[†]	10.85	.67	....	100.20	
Hollidaysburg: Manning & Lewis	II	Lewistown	96.16	1.59	.03[†]	1.61	.79	....	100.18	
Isitt: C. L. Myers	I	Ordovician	72.42	9.09	6.01	12.47	....	.01	100.00	
Martinsburg: Isaac Campbell	III	Ordovician	91.08	3.99	.86	3.07	1.05	....	100.05	
Martinsburg: John Manning	I	Ordovician	98.00	....	....	....	....	2.00	100.00	
Mt. Etna Furnace	II	Ordovician	94.98	3.87	.26	.91	.16	....	100.18	
Rodman Furnace: Bl. gray stone	II	Ordovician	78.18	10.75	1.85	8.57	.44	.21	100.00	
Rodman Furnace: Bl. gray stone	II	Ordovician	91.89	2.87	.64	4.38	.29	....	100.07	
Rodman Furnace: Pearl gray stone	II	Ordovician	64.57	44.18	.23	1.38	.06	....	?	
Springfield Furnace: Dark blue	II	Ordovician	78.20	17.51	1.13	3.21	.38	....	100.33	
Tyrone Twp.: Light bl. gray stone	II	Ordovician	90.39	2.24	1.68	5.88	....	....	100.19	
Tyrone Twp.: Bluish gray stone	II	Ordovician	92.11	4.23	.19	3.62	....	....	100.15	
Tyrone (Snyder Twp.): Keystone Lime & Stone Co	I	Lewistown	96.00	2.00	....	2.00	....	....	100.00	
Tyrone (Snyder Twp.): American Stone & Lime Co	I	Lewistown	92.51	2.22	.87	4.40	....	....	100.00	
BRADFORD COUNTY.										
Burlington (1 m. E.)	II	Burlington	73.21	2.31	7.00	18.00	.45	....	100.97	Lime, red with white spots; slakes readily; swells double.
Burlington (¼ m. E.): C. R. Montgomery	I	Burlington	53.79	2.09	9.44	30.18	3.73	.77	100.00	
Granville Center: L. D. May	I		63.00	1.93	....	26.67	....	8.40	100.00	
BUTLER COUNTY										
Branchton: Branchton Limestone Co	I	Vanport	84.00	3.96	2.42	6.85	....	2.77	100.00	
Rough Run: T. K. Morris	III		95.67	1.74	2.57	....	.03	....	100.01	
West Winfield: T. K. Morris	III		95.10	1.12	1.00	2.78	....	....	100.00	
Wick: Climax Lime & Stone Co	III		96.20	1.25	1.77	.78	....	....	100.00	
Wick: Climax Lime & Stone Co	III		93.70	.50	1.40	3.70	....	.70	100.00	

Analyses of Pennsylvania Limestones, by Counties—(Cont.)

LOCATION AND OWNER.	Source of Analyses	Geological Formation	COMPOSITION (PER CENT.) Calcium Carbonate	Magnesium Carbonate	Iron and Aluminum Oxids	Sand, clay, etc. (Insoluble)	Other minerals	Undetermined	Total
CAMBRIA COUNTY.									
Ashville, (2 m. E.) : Cassidy	I	Freep't Up(?)	93.31	1.45	2.00	3.24	....	....	100.00
Ashville, (3 m. E.) : Cassidy	I	Freep't Up(?)	82.99	4.48	3.67	5.72	....	3.18	100.00
Johnstown : A. J. Hawes	II	Johnstown	34.30	21.65	4.66	27.87	.02	11.50	100.00
Libby :	I	Freep't Up(?)	69.43	14.66	5.79	6.25	....	3.87	100.00
Patton	I	Conemaugh Series?	80.79	1.55	3.33	12.34	....	1.99	100.00
Wilmore	I	Conemaugh Series?	71.70	2.60	4.12	18.89	....	2.69	100.00
CENTRE COUNTY.									
Aaronsburg : (S. E.)	I	Ordovician	92.54	1.59	.80	4.60	....	.47	100.00
Bellefonte : American Stone & Lime Co :									
Quarry 22, side ledge	V	Ordovician	94.10	2.12	.90	2.88	....	....	100.00
Quarry 22, side ledge	V	Ordovician	94.10	2.34	.86	2.70	....	....	100.00
Quarry 22, side ledge	V	Ordovician	98.17	.77	.22	.84	....	....	100.00
Quarry 22, side ledge	V	Ordovician	96.45	1.99	.26	1.30	....	....	100.00
Quarry 22, side ledge	V	Ordovician	98.43	1.05	.16	.36	....	....	100.00
Quarry 22, side ledge	V	Ordovician	97.81	.93	.24	1.02	....	....	100.00
Quarry 13, face	V	Ordovician	98.05	1.27	.18	.50	....	....	100.00
Quarry 13, face	V	Ordovician	97.40	1.34	.22	1.04	....	....	100.00
Quarry 13, face	V	Ordovician	98.42	.84	.26	.48	....	....	100.00
Quarry 13, face	V	Ordovician	96.85	2.15	.31	.69	....	....	100.00
Quarry 13, side ledge	V	Ordovician	96.20	1.30	.32	2.20	....	....	100.00
Quarry 13, side ledge	V	Ordovician	92.14	2.94	.60	4.32	....	....	100.00
Quarry 13, side ledge	V	Ordovician	91.90	3.50	.88	3.72	....	....	100.00
Commercial samples	I	Ordovician	89.48	3.09	.96	6.54	.13	....	100.20
Commercial samples	I	Ordovician	97.85	.64	....	1.05	....	.46	100.00
Commercial samples	I	Ordovician	90.76	2.78	....	6.01	....	1.50	100.00
Bellefonte : American Stone & Lime Co	III	Ordovician	98.50	.87	.19	.79	.15	....	100.00
Bellefonte : Shortlidge Quarries	II	Ordovician	97.89	1.28	.20	.54	....	.09	100.00
Bellefonte : Shortlidge Quarries	II	Ordovician	98.32	1.17	.32	.39	....	....	100.20
Bellefonte : Shortlidge Quarries	II	Ordovician	97.53	1.21	.81	.81	....	.07	100.00
Bellefonte, (R. D. 1) ; Austin Dunlap	I	Ordovician	97.58	....	....	.62	....	1.80	100.00
Benore, (1 m. W.) : A. & N. Gray	I	Ordovician	90.72	2.42	....	8.04	....	....	101.18
Benore : W. H. Ghaner	I	Ordovician	90.50	1.78	....	8.38	....	....	100.62
Benore : W. H. Ghaner	I	Ordovician	91.87	....	....	4.06	....	1.62	100.50
Bloomsdorf, (½ m. N.) : H. Grenoble	I	Ordovician	56.18	27.21	8.28	10.12	....	3.21	100.00
Bloomsdorf : H. Grenoble	I	Ordovician	76.45	2.55	1.30	16.46	....	3.24	100.00

CENTRE COUNTY—(Cont.)										
Boalsburg: W. C. Myers	I	Ordovician	84.83	....	....	6.46	....	8.71	100.00	
Boalsburg: W. C. Myers	I	Ordovician	75.03	....	....	11.68	....	13.29	100.00	
Boalsburg: Mrs Boal (top of hill)	I	Ordovician	84.89	2.11	1.29	8.08	....	3.68	100.00	
Boalsburg: Mrs. Boal (quarry)	I	Ordovician	60.39	28.80	2.06	7.65	....	1.11	100.00	
Boalsburg: Mrs. Boal (Nittany farm)	I	Ordovician	63.37	30.68	2.77	2.83	....	.35	100.00	
Boalsburg, (½m. W.): T. D. Boal farm	I	Ordovician	91.30	2.77	.74	5.03	....	.16	100.00	Lime, white; slakes quickly to fine powder; swell, 3-fold.
" (½ m. N.): T. D. Boal, Foster farm	I	Ordovician	89.59	2.15	1.02	7.06	....	.18	100.00	Like the foregoing.
" (½ m. S.): T. D. Boal, Tussey farm	I	Ordovician	94.99	1.92	.64	2.52	....	....	100.07	Lime, white; slakes quickly to fine powder; swell, 3-fold.
" T. D. Boal, Oak Hall farm	I	Ordovician	76.18	14.36	2.81	5.87	....	.78	100.00	Lime, white; slakes slowly, but well.
Centre Hall: F. H. Baird	I	Ordovician	96.43	1.95	.64	2.74	....	....	101.76	
Centre Hall: Mrs. Reeves	I	Ordovician	48.22	36.96	....	10.02	....	4.80	100.00	
Fairbrook: McWilliams	I	Ordovician	94.14	1.94	.67	2.78	....	.47	100.00	
Fairbrook: (½ m. W.): Wm. Meek	I	Ordovician	61.00	33.49	2.45	3.32	....	....	100.26	
Fairbrook, (½ m. N.): A. B. Campbell	I	Ordovician	79.66	3.79	1.53	14.47	....	.55	100.00	
Fairbrook, (1 m. S.): H. Koch (gray stone)	I	Ordovician	92.28	4.13	.60	3.41	....	....	100.37	
Fairbrook: H. Koch (dark blue stone)	I	Ordovician	49.01	35.18	1.82	14.24	....	....	100.25	
Ferguson Twp.: Jas. A. Beaver	I	Ordovician	88.36	7.52	....	5.64	....	....	101.52	
Fillmore: John Rockey	I	Ordovician	98.55	....	....	1.10	....	.35	100.00	
Fillmore; John Rockey	I	Ordovician	82.16	....	....	10.62	....	7.22	100.00	
Howard, (1¾ m. N. E.): H. Pletcher	I	Chemung?	68.99	1.59	4.27	20.97	....	4.18	100.00	
Howard, (1¾ m. N. E.): H. Pletcher	I	Chemung?	86.46	1.74	1.86	8.99	....	.95	100.00	
Lemont: M. Baker	I	Ordovician	95.88	....	....	2.93	....	1.19	100.00	Lime, white; slaked well; swell, double.
Lemont: H. K. Whittle	I	Ordovician	89.87	3.15	.90	5.70	....	.38	100.00	
Lemont (1m. W.): W. F. Thompson; 2nd bed.	I	Ordovician	75.52	18.52	.91	5.25	.06	....	100.20	
Lemont (1 m. W.): W. F. Thompson; 3rd bed	I	Ordovician	88.66	6.03	.71	4.49	.05	.06	100.00	
Linden Hall: J. H. Ross	I	Ordovician	48.77	36.43	....	5.61	....	9.19	100.00	
Linden Hall: J. H. Ross	I	Ordovician	51.45	39.77	....	6.06	....	2.72	100.00	
Madisonburg; U. S. Shaffer	I	Ordovician	96.32	1.82	.67	2.42	....	....	101.23	
Madisonburg; U. S. Shaffer	I	Ordovician	97.88	1.15	.00	1.82	....	....	100.85	
Madisonburg (1 m. E.): U. S. Shaffer	I	Ordovician	84.90	12.66	....	2.31	....	.13	100.00	Lime, white; slaked slowly and imperfectly.
Miles Church (1 m. W.); John Dreibelbis	I	Ordovician	50.67	38.64	8.03	3.32	....	....	100.66	
Miles Twp.: H. E. Bierly	I	Ordovician	97.42	1.17	.65	.75	....	.01	100.00	
Miles Twp.: H. E. Bierly	I	Ordovician	98.22	1.09	.40	.40	....	....	100.11	
Miles Twp.: H. E. Bierly	I	Ordovician	95.19	2.84	.60	1.15	....	.22	100.00	
Miles Twp.: H. E. Bierly	I	Ordovician	89.48	8.90	.55	1.25	....	....	100.18	
Oak Hall: P. Dale	I	Ordovician	87.64	2.52	....	6.51	....	3.33	100.00	
Oak Hall: P. Dale	I	Ordovician	91.27	2.20	....	5.96	....	.57	100.00	
Oak Hall: P. Dale	I	Ordovician	67.00	2.23	....	16.07	....	14.70	100.00	
Oak Hall: P. Dale	I	Ordovician	87.78	1.62	....	5.89	....	4.71	100.00	
Pinegrove Mills (2 m. N. W.): J. H. Neidigh	I	Ordovician	51.79	32.48	....	12.98	....	2.75	100.00	
Pleasant Gap: White Rock Quarries	III	Ordovician	97.75	.23	.70	1.32	....	....	100.00	
Pleasant Gap: White Rock Quarries	III	Ordovician	99.01	.34	.22	4.30	....	....	100.00	
Pleasant Gap: (3 m. E.): Gentzel farm	I	Ordovician	97.23	....	....	1.45	....	1.32	100.00	

Analyses of Pennsylvania Limestones, by Counties—(Cont.)

LOCATION AND OWNER.	Source of Analyses	Geological Formation	COMPOSITION (PER CENT.) Calcium Carbonate	Magnesium Carbonate	Iron and Aluminum Oxids	Sand, clay, etc. (Insoluble)	Other minerals	Undetermined	Total	Burning Test
CENTRE COUNTY—(Cont.)										
Pleasant Gap: (3 m. E.): Gentzel farm....	I	Ordovician	98.92	....	....	.92	....	.16	100.00	
Pleasant Gap: (3 m. E.): Gentzel farm....	I	Ordovician	98.21	....	....	.85	....	.94	100.00	
Pleasant Gap: (3 m. E.): Gentzel farm....	I	Ordovician	86.54	....	....	9.82	....	3.64	100.00	
Potter's Mills (1 m. W.): Jas. Reish (blue stone)........	I	Ordovician	70.44	2.59	2.68	23.23	....	1.06	100.00	Lime, yellowish; slaked slowly, but well; swell, ⅓.
Potter's Mills (1 m. W.): Jas. Reish (gray stone)	I	Ordovician	89.80	1.85	.78	7.54	....	.03	100.00	Lime, gray; slakes more quickly than foregoing; swell, 2-fold
Rebersburg: H. E. Bierly........	I	Ordovician	88.82	1.66	....	6.74	....	2.78	100.00	
Rebersburg: H. E. Bierly........	I	Ordovician	92.09	3.38	....	2.88	....	1.65	100.00	
Rebersburg: H. E. Bierly........	I	Ordovician	96.25	2.08	....	.58	....	1.09	100.00	
Rebersburg: H. E. Bierly........	I	Ordovician	97.80	1.26	....	.61	....	.33	100.00	
Rock Creamery (¾ m. S.W.): D. F. Houser.	I	Ordovician	89.76	4.24	....	6.31	....	....	100.31	
Rock Creamery: W. F. Reynolds........	I	Ordovician	87.12	2.82	....	9.18	....	.88	100.00	
Ross's Church: C. M. Henderson (dark gray stone)	I	Ordovician	52.53	41.79	1.92	4.36	....	....	100.60	Lime, yellow-white; slaked quickly; swell, double
Ross's Church: C. M. Henderson (light gray stone)	I	Ordovician	53.58	40.81	1.28	4.54	....	....	100.21	Lime, white; slaked quickly; swelled double.
Ross's Church: A. S. Ellenberger (dark blue stone)	I	Ordovician	82.51	3.82	2.82	7.88	....	2.97	100.00	Lime, white; slaked quickly; swelled over 2-fold.
Ross's Church: A. S. Ellenberger (dark gray stone)	I	Ordovician	69.03	11.63	2.94	14.00	....	1.70	100.00	Lime, mottled yw.-white; slaked slowly and imperfectly.
Snow Shoe........	II	Allegheny S's	42.94	22.76	....	18.73	1.61	13.96	100.00	
Snow Shoe........	II	Allegheny S's	51.15	13.26	....	23.53	.66	11.40	100.00	
Snow Shoe: J. R. Irvin........	I	Allegheny S's	81.61	3.15	....	10.73	....	4.51	100.00	
Spring Mills (2 m. S.): J. W. Evans (shaley stone)........	I	Ordovician	84.02	Trace	1.57	18.39	....	2.59	100.00	
Spring Mills: J. W. Evans (blue stone)........	I	Ordovician	74.80	Trace	1.69	24.10	....	1.10	100.00	
Spring Mills R. D. 4: R. I. Smith........	I	Ordovician	94.66	1.59	.64	3.26	....	....	100.15	
State College (1⅓ m. N.) R. Brennan, (surface)	I	Ordovician	45.86	38.24	....	15.06	....	.84	100.00	
State College: R. Brennan (quarry veins).	I	Ordovician	51.89	40.74	....	5.87	....	1.50	100.00	

CENTRE COUNTY—(Cont.)										
State College, (1 m. W.) : A. Albright......	I	Ordovician	92.80	3.29	.30	3.89	....	....	100.28	Lime, white; slaked slowly, but well.
" (½ m. S. W.) ; N. E. Dreibellia..	I	Ordovician	84.70	3.95	1.03	10.67	....	....	100.35	Lime, white; slaked very slowly, but fairly well.
" (2 m. S. W.) : Mrs. Geo. Homan.	I	Ordovician	54.43	18.55	2.40	22.90	2.89	....	100.29	Lime, white; absorbed water readily, but did not heat or slake.
" (3 m. S.W.) : J. N. Hoy, (top bed)	I	Ordovician	86.36	.19	4.17	5.33	....	3.95	100.00	
" J. N. Hoy (2nd bed)	I	Ordovician	87.16	.46	4.45	4.30	....	3.63	100.00	
" J. N. Hoy (3rd bed).	I	Ordovician	85.65	.36	3.62	5.78	....	4.59	100.00	
" J. N. Hoy (4th bed).	I	Ordovician	85.59	1.09	1.25	8.25	....	3.82	100.00	
" (3 m. S. S. W.) : N. E. Hess.....	I	Ordovician	76.74	7.58	3.80	12.00	....	....	100.12	Lime, white with dark pink spots; slaked slowly but completely; swells double.
" (4 m. S. W.) : M. Dreibelbis...	I	Ordovician	94.44	....	....	2.00	....	3.56	100.00	
" M. Dreibelbis......	I	Ordovician	71.59	....	....	21.88	....	6.53	100.00	
" M. Dreibelbis......	I	Ordovician	88.21	....	....	7.55	....	4.24	100.00	
" M. Dreibelbis......	I	Ordovician	91.90	....	....	4.70	....	3.40	100.00	
" (½ m. S.) : McCoy..........	I	Ordovician	81.56	Trace	1.36	17.08	....	....	100.00	
" (½.m.S.S.E.) : W. O'Bryan (1st quarry, upper bed)...........	I	Ordovician	88.71	1.71	1.65	7.30	....	.63	100.00	
" W. O'Bryan (1st quarry, 2d bed)	I	Ordovician	90.33	1.35	1.67	6.34	....	1.31	100.00	
" W. O'Bryan (2nd quarry).......	I	Ordovician	93.33	4.20	.56	2.30	....	....	100.39	
Zion: Amos Kauffman..................	I	Ordovician	90.28	....	....	4.98	....	4.74	100.00	
Zion: Amos Kauffman..................	I	Ordovician	84.55	....	....	6.50	....	8.95	100.00	
Zion: Amos Kauffman..................	I	Ordovician	96.76	....	....	1.22	....	2.02	100.00	
Zion: Amos Kauffman..................	I	Ordovician	91.41	....	....	3.55	....	5.04	100.00	
CHESTER COUNTY.										
Avondale: F. Williamson & Co............	III	Ordovician	94.27	1.56	.26	3.91	....	....	100.00	
Avondale: F. Williamson & Co............	III	Ordovician	93.31	1.85	.40	4.44	....	....	100.00	
" F. Williamson & Co., (white stone)	III	Ordovician	97.50	.75	1.04	.84	.009	....	100.139	
" F. Williamson & Co., (blue stone)..	III	Ordovician	84.07	11.14	1.26	3.50	.012	....	99.982	
" F. Williamson & Co., (gray stone).	III	Ordovician	73.48	15.59	3.58	7.14	.012	....	99.802	
" Avondale Lime & Stone Co.........	IV	Ordovician	75.00	20.00	....	5.00	....	....	100.00	
" Avondale Marble Co.............	IV	Ordovician	58.01	40.38	....	1.61	....	....	100.00	
" H. Palmer.....................	I	Ordovician	55.79	39.54	1.64	4.28	....	....	101.25	
Barker Station: Acme Lime Co..........	IV	Ordovician	58.52	3.87	1.91	36.27	.07	....	100.64	
Barker Station: Acme Lime Co., (marble)..	IV	Ordovician	83.39	12.42	.39	4.65	.04	....	100.89	
Berwyn: Annie W. Miller................	I	Ordovician	64.00	22.99	3.12	9.89	....	....	100.00	
Berwyn: S. Lawrence Bodine............	I	Ordovician	54,88	21.56	10.27	13.29	....	....	100.00	
Cedar Hollow: Warner Bros............	I	Ordovician	51.97	44.23	1.53	2.27	....	....	100.00	
Devault: Chas. Warner Co..............	III	Ordovician	53.59	42.71	.37	2.80	.53	....	100.00	
Devault: Chas. Warner Co..............	III	Ordovician	56.64	38.56	1.16	1.68	....	1.96	100.00	
Devault: Chas. Warner Co..............	III	Ordovician	57.12	38.94	.84	2.04	....	1.06	100.00	
Devault: Chas. Warner Co..............	III	Ordovician	51.74	43.34	.64	1.74	....	2.54	100.00	
Londongrove Twp.: Swayne............	II	Ordovician	54.07	43.31	.61	1.95	.04	.02	100.00	
Mill Lane Station: Knickerbocker Lime Co.	III	Ordovician	65.00	30.00	....	....	....	5.00	100.00	
Tanguy..............................	I	Ordovician	67.52	25.66	4.40	2.42	....	....	100.00	

Analyses of Pennsylvania Limestones, by Counties—(Cont.)

LOCATION AND OWNER.	Source of Analyses	Geological Formation	COMPOSITION (PER CENT.) Calcium Carbonate	Magnesium Carbonate	Iron and Aluminum Oxids	Sand, clay, etc. (Insoluble)	Other minerals	Undetermined.	Total	Burning Tests
CLARION COUNTY.										
Clarion Twp.: Hindman's Quarry	II	Vanport	95.53	.93	1.05	1.96	.15	.38	100.00	
New Athens	II	Freep't Up.	93.80	2.27	.76	1.80	.02	1.35	100.00	
Perry Twp.: Barger Quarry	II	Vanport	96.43	1.20	.87	1.11	.05	.34	100.00	
Perry Twp.: Reichart's Quarry	II	Freep't Up.	82.68	8.25	1.36	5.32	.05	2.32	100.00	
Porter Twp.: On Long Run	II	Vanport	95.23	.41	1.31	2.19	.13	.73	100.00	
Sligo Furnace	II	Vanport	95.20	1.26	1.53	1.78	.17	.06	100.00	
Toby Twp.	II	Freep't Up.	82.00	6.31	2.74	7.94	.03	.98	100.00	
CLEARFIELD COUNTY.										
Cherrydale: G. Kolivoske(?)	I	Allegheny S's	61.99	3.24	4.64	29.68	....	.55	100.00	
Cherrydale: G. Kolivoske	I	Allegheny S's	52.21	1.86	9.05	37.14	....	.95	100.00	
Coalport (1m. S. E.)	I	Allegheny S's	44.10	3.08	6.33	42.66	....	3.83	100.00	
Glen Hope: Caldwell's Quarry	II	Allegheny S's	93.81	1.71	....	2.07	.15	2.26	100.00	
Grampian (?)	I	Allegheny S's	75.55	.70	4.63	17.12	....	2.00	100.00	
Kerrmoor (?)	I	Allegheny S's	70.49	2.57	8.64	18.30	....	....	100.00	
Lecontes Mills: Mrs. Fannie Smith	I	Allegheny S's	83.66	2.39	....	9.55	....	4.40	100.00	
Sabula	I	Allegheny S's	89.39	2.23	....	6.39	....	1.99	100.00	
CLINTON COUNTY.										
Cedar Spring: L. Furst	I	Ordovician	93.20	....	3.43	1.25	....	2.12	100.00	
Cedar Spring: L. Furst	I	Ordovician	93.00	....	2.14	2.29	....	2.57	100.00	
Cedar Spring: L. Furst	I	Ordovician	87.60	....	3.53	3.13	....	5.74	100.00	
Crawford Twp.: J. Wilshans	II	Ordovician	95.07	1.04	....	2.66	1.22	.01	100.00	
COLUMBIA COUNTY.										
Almedia	I	Lewistown(?)	87.43	4.13	1.05	6.33	....	1.06	100.00	
Bloomsburg: Mrs. D. J. Waller, Jr.	III	Lewistown(?)	94.18*	1.30*	1.67	2.53	.33	....	100.01	
" Paragon Lime and Limestone Co.	II	Lewistown(?)	90.06*	1.65*	2.83*	5.46*	....	....	100.00	
" Trembly Quarry, (coarse)	I	Lewistown(?)	38.54	17.29	....	25.88	....	18.29	100.00	
" Trembly Quarry, (fine)	I	Lewistown(?)	39.88	17.81	....	39.88	....	22.29	100.00	
Centre Twp.: Low Quarry	I	U., 5 ft. dark stone	88.45	4.78	.66	6.26	.04	....	100.19	
	II	Ib., Overlying "Bastard".	82.37	7.79	1.19	8.83	.05	....	100.23	
	II	Ib., Bastard	70.98	5.68	3.44	19.51	.07	.87	100.00	
	II	Ib., Upper Bossardville	92.31	3.90	.53	3.34	.01	....	100.09	

*Recalculated.

COLUMBIA COUNTY—(Cont.)										
Centre Twp.: Low Quarry...............	II	Ib., Middle Bossardville	96.21	1.77	.50	1.82	.01	....	100.31	
	II	Ib., Lower Bossardville	94.27	1.93	.55	3.48	.04	....	100.27	
	II	Ib., Lower Bossardville	93.38	2.00	.63	4.17	.08	....	100.21	
CRAWFORD COUNTY.										
Centreville(?)	I	?	86.13	1.02	8.19	9.53	....	.13	100.00	
Cochrantown (?).........................	I	?	80.17	1.29	2.50	15.58	....	.46	100.00	
Wayne Twp.: Shuey's Quarry............	II	Meadville, Lower.....	27.61	1.70	4.24*	60.43	6.29	.35	100.00	
CUMBERLAND COUNTY.										
Bowmansdale: H. A. Miller..............	III	Ordovician	94.55	....	5.71*	8.21	5.63	....	108.96?	
Bridgeport: Walton Quar., Bed 111. Lo.part.	II	Ordovician	94.5	2.7	....	1.3	....	1.5	100.00	
" Walton quarry, Bed 112, lower part.	II	Ordovician	54.4	35.2	....	8.4	....	2.0	100.00	
" Walton quarry, Bed 113, lower part.	II	Ordovician	98.1	.9	....	1.0	....	....	100.00	
" Walton quarry, Bed 114, lower part	II	Ordovician	64.6	26.2	....	8.5	....	.7	100.00	
" Walton quarry, Bed 115, lower part.	II	Ordovician	95.1	1.9	....	.9	....	2.1	100.00	
Oakville (3 m. W.): Philip Taylor, (dark blue stone).........................	I	Ordovician	89.71	1.37	.72	7.56	....	.65	100.00	Lime, yw-white; slaked slowly, but well; swell, 2½-fold.
Oakville (3 m. S. W.) Philip Taylor (light gray stone).........................	I	Ordovician	90.24	4.19	.62	5.02	....	....	100.07	Lime, white; slaked slowly, but well; swell, 3-fold.
DAUPHIN COUNTY.										
Halifax: Ryter & Ryan................	I	Lewistown?	93.02	2.08	3.54	.65	.71	....	100.00	
Harrisburg: Couffer Quarry............	II	Ordovician	67.75	28.43	....	4.25	.01	1.56	100.00	
Harrisburg: Crumbler Quarry...........	II	Ordovician	92.00	4.54	....	2.55	....	.91	100.00	
Harrisburg: Frantz.....................	II	Ordovician	70.50	11.73	....	7.45	....	1.32	100.00	
Harrisburg: Huffman & Wilson..........	III	Ordovician	87.68	9.46	1.72	2.29	....	....	101.15	
Harrisburg: Huffman & Wilson..........	III	Ordovician	89.30	6.70	1.00	3.00	....	....	100.00	
Harrisburg: Rutherford, East Quarry.....	II	Ordovician	86.12	8.86	.36	4.30	.43	1.93	100.00	
Harrisburg: Rutherford, West Quarry....	II	Ordovician	90.62	6.17	.60	2.51	.25	....	100.15	
Harrisburg: Strickler....................	II	Ordovician	69.25	26.25	....	2.75	....	1.75	100.00	
Hummelstown: Vulcanite Limestone Co..	III	Ordovician	95.00	....	.02*	.03	....	4.95	100.00	
Steelton: Penn'a Steel Co................	III	Ordovician	89.50	7.00	Trace	8.50	....	....	100.00	
Swatara: Walter T. Bradley.............	III	Ordovician	98.77	.30	.17	.62	....	.14	100.00	
Swatara: Walter T. Bradley.............	III	Ordovician	98.85	....	.60	.55	....	....	100.00	
Swatara: Walter T. Bradley.............	III	Ordovician	98.10	....	.12	.12	....	1.66	100.00	
ELK COUNTY.										
Benezette, (1 m. W.): Upper bed........	II	Benezette	86.78	1.41	10.07	50.67	....	1.07	100.00	
Benezette: Middle bed..................	II	Benezette	76.14	1.74	3.68	15.98	....	2.46	100.00	
Benezette, (2 m. N. E.): G. W. Winslow..	II	Vanport	86.91	6.66	2.20	2.39	.04	1.80	100.00	
Brandy Camp: J. C. McAllister..........	II	Vanport	91.78	1.81	1.71	3.37	.07	1.26	100.00	
Brandy Camp: J. C. McAllister..........	II	Johnstown	50.36	2.47	7.04	36.86	.11	3.16	100.00	

* Aluminum only.

Analyses of Pennsylvania Limestones, by Counties—(Cont.)

LOCATION AND OWNER.	Source of Analyses	Geological Formation	COMPOSITION (PER CENT.) Calcium Carbonate	Magnesium Carbonate	Iron and Aluminum Oxids	Sand, clay, etc. (Insoluble)	Other minerals	Undetermined	Total	Burning Tests
ELK COUNTY—(Cont.)										
Brandy Camp: J. C. McAllister..........	II	Freep't Lo.	69.36	9.81	4.83	13.68	.16	2.66	100.00	
" (1½ m. S.): J. S. Chamberlain..	II	Freep't Lo.	81.87	7.19	2.75	6.54	.14	1.51	100.00	
" (1 m. S.): J. S. Hyde..........	II	Freep't Up.	80.36	1.62	3.61	12.29	.18	1.94	100.00	
Brockport: Oyster's Quarry, upper bed...	II	Vanport	27.86	.98	3.83	61.67	.13	5.53	100.00	
Brockport: Oyster's Quarry, middle bed...	II	Vanport	54.55	1.13	3.03	38.95	.21	2.13	100.00	
Brockport: Oyster's Quarry, lower bed....	II	Vanport	49.73	1.33	3.65	41.69	.50	3.10	100.00	
Brockport, (¾ m. N.): T. Fox...........	II	Freep't Lo.	57.32	8.85	7.94	21.25	.08	4.56	100.00	
Fox Twp., (1 m. E.): J. S. Chamberlain's.	II	Vanport	86.21	1.78	2.61	7.37	.12	1.91	100.00	
Wilcox, (4 m. E.): Gen. Kane's, upper bed.	I	Vanport(?)	89.93	1.32	....	5.65	....	3.80	100.00	
St. Marys: J. M. Wittman..............	II	Vanport	94.36	1.63	1.64	1.63	.07	.20	100.00	
Wilcox, (4 m. E.): Gen. Kane's, Up. bed.	II	Vanport	94.11	1.37	1.63	2.20	.14	.55	100.00	
FAYETTE COUNTY.										
Leisenring, (½ m. S. W.): H. W. Berricklow	I	?	66.25	8.50	6.41	17.49	....	1.35	100.00	
Lemont: Furnace Quarry................	II	Pittsburgh	87.37	1.73	2.04	7.36	.86	.64	100.00	
Lemont: Furnace Quarry................	II	Redstone	66.47	17.71	5.99	9.46	.30	.07	100.00	
Oliphant: Furnace Quarry...............	II	Fishpot	80.65	2.22	.54*	10.77	5.16	.66	100.00	
Star Junction (1 m. N.)................	I	?	54.57	20.83	3.90	17.20	2.58	.97	100.00	
Vanderbilt, (½ m. N.): A. J. Hill heirs, Round Top..........................	I	?	87.48	4.55	1.41	4.60	....	1.96	100.00	
Vanderbilt, (¾ m. E.)										
" A. J. Hill heirs: State Road Qu.	I	?	43.57	12.70	12.27	21.93	....	.53	100.00	
" (½ m. N.): A. J. Fairchild......	I	?	74.66	5.24	2.70	17.27	....	.13	100.00	
FOREST COUNTY										
Tionesta: Kelly.........................	II	Tionesta	40.64	1.17	2.12*	55.16	.04	.87	100.00	
FRANKLIN COUNTY.										
Chambersburg: A. H. Pheil Quarry........	I	Ordovician	92.85	2.26	1.20	4.19	....	....	100.00	Lime, white; slaked quickly and well; swells, 3-fold.
Edenville, (1½ m. S.W.): Ledge on Nor. Mt.	I	Ordovician	94.51	1.61	.76	1.84	.60	.68	100.00	
Mont Alto: Mine No. 3.................	II	Ordovician	89.18	.96	.81	8.84	.11	.10	100.00	
Mont Alto: Mine No. 4.................	II	Ordovician	54.39	42.69	.94	2.16	.03	....	100.21	
Mont Alto: Shiery property (dolomite)...	II	Ordovician	51.74	43.44	.54	4.09	.06	.13	100.00	
Quincy: Harshman Quarry..............	II	Ordovician	95.48	2.26	.44	2.34	....	....	100.52	
Scotland: Beitin Quarry (cement rock)...	II	Ordovician	47.37	15.58	6.76	29.64	....	.64	100.00	
Williamson: Hawbecker quarry (best rock)	II	Ordovician	97.32	1.29	.26	.98	.01	.14	100.00	
" Hawbecker Quarry (poorest rock)	II	Ordovician	67.26	30.70	.70	1.76	.02	....	100.44	

* Aluminum oxid only.

FULTON COUNTY.									
Enid: Owner unknown	I	Loyalhanna?	47.25	.15	....	45.92	....	6.68	100.00
Enid: Owner unknown	I	Loyalhanna?	83.84	.18	....	12.58	....	3.45	100.00
Enid: Owner unknown	I	Loyalhanna?	91.38	.15	....	5.08	....	3.39	100.00
HUNTINGDON COUNTY.									
Bermingham: R. Seeds (sand)	I	Ordovician	42.79	53.84	1.67	1.80	....	....	100.00
Bermingham: R. Seeds (ledge)	I	Ordovician	92.58	2.47	.07	5.05	....	....	100.17
Broadtop City: J. Diggins	II	Greenbrier or Loyalhanna	46.23	2.56	5.18	34.64	.58	.86	100.00
Charter Oak: Old Phillips farm	I	Salina, Clint'n	74.13	3.72	2.44	19.57	....	.14	100.00
Grafton: Powell Iron Co., (upper gray bed)	II	Lewistown	95.54	1.59	.49	1.85	.02	.51	100.00
" Powell Iron Co., (lower gray bed)	II	Lewistown	98.03	.91	.41	.42	.02	.21	100.00
" Powell Iron Co., (4-ft. ironstone bed)	II	Lewistown	94.64	2.80	.87	1.73	.01	.45	100.00
" Powell Iron Co., (5-ft. gray bed)	II	Lewistown	95.45	1.13	.52	2.35	.01	.54	100.00
" Powell Iron Co., (7-ft. black bed)	II	Lewistown	93.03	1.82	.73	3.48	.01	.95	100.00
Hosher's Mines: (dark gray stone)	II	Ordovician	72.67	3.98	3.81*	18.05	1.49	....	100.00
Hosher's Mines: (pale ash-gray stone)	II	Ordovician	51.25	42.39	.82*	5.03	.51	....	100.00
Hosher's Mines: (yellowish gray stone)	II	Ordovician	45.73	35.51	1.75*	15.83	.12	....	100.00
McAlevy's Fort, (2 m. S. E.): Barr's farm	II	Salina, Clint'n	88.69	1.85	1.44	8.23	.42	....	100.63
" (½ m. N.) Barr's farm	I	Salina, Clint'n	90.46	1.95	....	5.03	....	2.56	100.00
" (3 m. E.): Sander's farm	I	Salina, Clint'n	94.02	2.48	....	2.87	....	.83	100.00
" (1½ m. S. E.): Cummin's farm	I	Salina, Clint'n	94.17	1.59	....	3.20	....	1.14	100.00
McAlevy's Fort, (2 m. S. E.); Beaty farm	I	Salina, Clint'n	92.98	1.89	....	4.48	....	.70	100.00
" (2 m. S. S. E.): McMahon farm	I	Salina, Clint'n	93.30	1.58	....	3.93	....	1.19	100.00
Memphis: Owner unknown	II	Barree	96.00	....	....	....	....	4.00	100.00
Memphis: Owner unknown	II	Barree	91.00	....	....	....	....	9.00	100.00
Memphis: Owner unknown	II	Barree	90.00	2.00	1.79	5.66	.03	.52	100.00
Mt. Union: Outcrop, Chestnut Ridge, 40 ft. up	I	Lewistown?	95.64	....	....	3.99	....	.37	100.00
" Outcrop, Chestnut Ridge	I	Lewistown?	93.25	....	....	4.72	....	2.03	100.00
" Outcrop, Chestnut Ridge, base	I	Lewistown?	80.96	....	....	11.82	....	7.22	100.00
Robertdale: Conglomerate with shale	II	Greenbrier or Loyalhanna	52.71	2.08	4.54‖	42.46	.41	....	102.20
Rockhill Furnace: John Beers	I	?	85.29	6.44	1.22	7.52	....	....	100.47
Rockhill Furnace: John Beers	I	?	89.20	2.21	1.64	6.59	....	.86	100.00
Saltillo: Water-lime cement, 375 ft. above bottom of formation	II	Lewistown?	70.56*	18.10*	1.26†	8.15‡	1.27	.66	100.00
Saltillo: Water-lime cement, 190 ft. above bottom of formation	II	Lewistown?	84.02*	9.43*	.55	5.32	.20	.48	100.00
Saltillo: Water-lime cement, 160 ft. above bottom of formation	II	Lewistown?	25.20*	19.64*	14.07	33.22	1.93	5.94	100.00
Saltillo: McCarthy, blue gray stone	II	Lewistown	89.29	2.86	1.78	5.30	.21	.86	100.00
Saltillo McCarthy, blue siliceous stone	II	Lewistown?	47.30	2.01	1.67	49.03	.42	....	100.43
Three Springs: Hudson farm, 70 ft. above bottom of formation	II	Lewistown?	90.90	2.16	.12‡	5.70	1.86	....	100.74
Three Springs: Hudson farm, 60 ft. above bottom of formation	II	Lewistown?	94.03	1.96	.70	2.38	.17	.81	100.00
Three Springs: Hudson farm, 50 ft. above bottom of formation	II	Lewistown?	91.12	1.57	1.14	5.04	.10	1.03	100.00

*Recalculated. ‖ Iron oxid only. † Aluminum oxid only. ‡ Silica only.

Analyses of Pennsylvania Limestones, by Counties—(Cont.)

LOCATION AND OWNER.	Source of Analyses	Geological Formation	COMPOSITION (PER CENT.) Calcium Carbonate	Magnesium Carbonate	Iron and Aluminum Oxids	Sand, clay, etc. (Insoluble)	Other minerals	Undetermined	Total	Burning Tests
HUNTINGDON COUNTY—(Cont.)										
Todd Twp.: John Whitney	II	Greenbrier or Loyalhanna	92.32	1.09	.18†	4.64	.79	1.18	100.00	
Union Furnace: H. J. McAteer	IV	Ordovician	92.95*	2.07*	.80	....	.02	2.91	100.00	
Warriorsmark Twp.: J. Lehman	I	Ordovician	52.94	42.69	.99	2.81	....	.57	100.00	
Warriorsmark Twp.: J. Lehman	I	Ordovician	50.18	36.54	2.24	11.83	....	....	100.79	
Warriorsmark Twp.: J. Lehman	I	Ordovician	57.84	31.14	2.27	9.00	....	....	100.25	
Warriorsmark Twp.: J. Lehman	I	Ordovician	43.12	30.40	3.01	22.52	....	.95	100.00	
Warriorsmark Twp.: McClelland Geist	I	Ordovician	97.70	1.11	.29	1.49	....	....	100.59	
" Frank V. Way (blue-gray stone)	I	Ordovician	51.58	42.86	1.19	1.75	....	2.62	100.00	
" Frank V. Way (dark blue stone)	I	Ordovician	54.08	41.91	1.92	1.41	....	.68	100.00	
Water Street: Penn'a Limestone Co	I	Ordovician	72.74	7.63	4.95	14.68	....	....	100.00	
INDIANA COUNTY.										
Black Lick, (1 m. E.): Tyhawk's Quarry	II	Johnstown	78.77	2.42	3.54	13.79	.28	1.20	100.00	
Blairsville, (4½ m. N. E.): P. Brown	II	Freep't Lo.	83.32	8.02	2.63	5.50	.29	.24	100.00	
Blairsville, (3 m. S. E.): C. Levingood	II	Freep't Up.	54.77	8.63	6.93	27.23	.32	2.12	100.00	
Blairsville, (½ m.): R. Smith	II	Fishpot	79.82	3.60	3.02	12.16	.33	1.07	100.00	
Chambersville, (1 m. E.): Graft Bros	II	Freep't Up.	84.41	2.80	2.12	9.15	.51	1.01	100.00	
Decker's Point, (¾ m. N. W.): S. Palmer	II	Freep't Lo.	88.23	1.37	1.96	8.21	.16	.07	100.00	
Dixonville: J. Edwards, (upper bed)	I	?	59.05	1.22	....	36.06	....	3.67	100.00	
Dixonville: J. Edwards (middle bed)	I	?	53.00	1.09	....	41.94	....	3.97	100.00	
Dixonville: J. Edwards (lower bed)	I	?	21.61	2.92	....	20.91	....	54.56	100.00	
Five Points, (1½ m. S. W.): S. Brown	II	Freep't Up.	84.12	5.20	3.22	6.02	.21	1.28	100.00	
Home: T. St. Clair Thompson(?)	I	?	83.88	8.19	3.10	4.86	....	...	100.03	
Home: T. St. Clair Thompson(?)	I	?	83.69	2.76	1.25	11.45	....	.85	100.00	
Home: T. St. Clair Thompson(?)	I	?	76.12	6.30	2.65	13.91	....	1.02	100.00	
Home: T. St. Clair Thompson(?)	I	?	46.07	16.30	....	23.21	....	14.42	100.00	
Home: T. St. Clair Thompson(?)	I	?	78.84	2.77	....	13.97	....	4.42	100.00	
Home: T. St. Clair Thompson(?)	I	?	43.66	5.69	....	38.27	....	12.88	100.00	
Homer, (1½ m. S. E.): D. R. Griffith	II	Freep't Up.	72.26	6.49	4.19	14.98	.28	1.85	100.00	
Indiana, (1): Homer Burkett(?)	I	?	65.44	2.82	6.44	21.06	....	4.74	100.00	{Lime, red. gray; slakes very slowly and imperfectly.
Jacksonville, (2 m. N.): S. C. Hazlett	II	Freep't Up.	89.82	1.80	1.70	5.48	.39	.86	100.00	
Richmond, (1½ m. S. W.): Simpson's Quarry	II	Vanport	92.86	1.59	2.03	2.09	.54	.89	100.00	
Rossiter: G. H. Elbel(?)	I	?	73.16*	.87*	9.20*	16.72*	....	....	100.00	
Smithport, (2 m. S. W.): A. Gorman, (upper part)	II	Johnstown	86.21	16.88	4.36†	32.79	8.34	1.41	100.00	

* Recalculated.

† Aluminum oxid only.

INDIANA COUNTY—(Cont.)										
Smithport: A. Gorman, (lower part)......	II	Johnstown	58.75	16.00	7.38	15.06	.28	2.53	100.00	
Strongstown, (¾ m. W.): A. Cresswell, (upper bed)	I	?	67.84	6.49	3.88	19.54	....	2.25	100.00	Lime, yellow; slakes slowly, but fairly well; swells, ¾.
Strongstown: A. Cresswell, (middle bed)..	I	?	.81.73	5.70	3.65	8.51	....	.41	100.00	Lime, yellow; slakes well; swells, 2½-fold.
Strongstown: A. Cresswell, (lower bed)...	I	?	76.84	5.82	4.48	10.72	....	2.14	100.00	Lime, yellow; slakes well; swells, 2-fold.
West Lebanon: A. H. Fulton...............	II	Pittsburgh	82.77	2.87	2.83	10.33	.41	.79	100.00	
JEFFERSON COUNTY.										
Big Run, (2 m. N. E.): Jas. Smith, 125 ft. above Freeport Upper coal.............	II	Conemaugh S.	75.36	9.33	4.23	9.78	.04	1.26	100.00	
Big Run: Jas. Smith, 200 ft. above F. U. coal	II	Conemaugh S.	92.50	2.50	1.53	2.39	.05	1.03	100.00	
Big Run, (2 m. N.): Jacob Smith, 150 ft. above F. U. coal..........................	II	Conemaugh S.	77.14	4.69	3.79	11.78	.15	2.45	100.00	
Brockwayville, (3 m. N. W.): C. Bovaird...	II	Vanport	94.39	1.70	1.31	1.91	.06	.63	100.00	
Brockwayville, (1 m. S. E.): N. B. Lane..	II	Johnstown	51.41	3.96	7.79	33.90	.07	2.87	100.00	
Brockwayville: N. B. Lane..............	II	Freep't Lo.	87.03	1.56	2.17	8.40	.12	.72	100.00	
Brockwayville: N. B. Lane..............	II	Freep't Up.	89.11	1.61	2.14	6.17	.05	.92	100.00	
Brookville: Bolton Quarry, 4-ft. bed......	I	?	84.11	....	....	10.23	....	5.66	100.00	
Brookville: Bolton Quarry, Boulder......	I	?	93.39	....	....	3.28	....	3.33	100.00	
Brookville: Bolton Quarry, Boulder......	I	?	94.11	....	....	2.61	....	3.23	100.00	
Brookville: Quarry adjacent to Bolton...	I	?	76.30	....	....	17.30	....	6.40	100.00	
Brookville: Quarry adjacent to Bolton...	I	?	73.56	....	....	17.10	....	9.34	100.00	
" Quarry ½ m. from Bolton, 4-ft. bed	I	?	93.78	....	....	4.42	....	1.80	100.00	
" Quarry 2½ m. from Bolton, 5-ft. bed	I	?	85.91	....	....	1.33	....	12.76	100.00	
Corsica, (½ m. E.): Evan's Round Top....	II	Freep't Lo.	92.86	1.68	2.32	2.07	.04	1.03	100.00	
Dowlingsville, (1 m. N.): S. Shields.....	II	Vanport	96.58	.83	.78	1.28	.08	.55	100.00	
Frostburg, (2 m. N. E.): D. Hopkins.....	II	Freep't Up.	91.87	2.42	1.31	3.13	.02	1.25	100.00	
Grove Summit: A. A. McCullough(?)....	I	?	56.21	5.95	....	34.68	....	3.16	100.00	
Grove Summit: W. T. Stuart(?)..........	I	?	44.28	1.95	....	41.26	....	12.51	100.00	
Perryville, (1 m. N. W.): John Iler......	II	Johnstown	82.39	1.89	4.65	8.02	.06	2.99	100.00	
Reynoldsville, (4 m. N); 40 ft. above lower Freeport coal.........................	I	?	87.86	1.77	2.03	6.06	....	2.78	100.00	
Sprankle's Mills, (2 m. N. E.): W. Hanna	II	Vanport	93.64	1.82	1.31	2.04	.06	1.13	100.00	
Sugar Hill: A. E. Calhoun's; 40 ft. above Freeport vein........................	I	?	85.82	4.77	2.79	7.22	....	....	100.60	
Sykesville: H. M. Buhite(?).............	I	?	52.72	1.72	5.32	87.47	....	2.77	100.00	Lime, reddish; slaked slowly and imperfectly.
Worthville, (½ m. S. E.): A. Enty........	II	Vanport	96.43	.91	.99	1.30	.07	.30	100.00	
Worthville, (2 m. N. E.): A. Hoffman....	II	Freep't Up.	88.93	1.59	1.74	6.77	.05	.92	100.00	
JUNIATA COUNTY										
Mexico: M. Rodgers(?)..................	I	Lewistown	95.03	....	....	2.16	....	2.81	100.00	
Mifflintown, (3 m. N.): Owner unknown...	I	Salina, Clint'n	89.68	.02	1.25	8.46	.09	.50	100.00	
Mifflintown, (3 m. N.): Owner unknown...	I	Salina, Clint'n	87.75	.13	1.25	10.06	.12	.69	100.00	
Mifflintown: J. M. Cauley(?)............	I	Salina, Clint'n	82.10	7.02	....	3.84	....	7.04	100.00	
Mifflintown: J. M. Cauley(?)............	I	Salina, Clint'n	90.91	2.83	....	2.34	....	3.92	100.00	
Mifflintown: D. Struffle..................	I	Salina, Clint'n.	85.49	2.00	1.68	11.17	....	....	100.34	

Analyses of Pennsylvania Limestones, by Counties—(Cont.)

LOCATION AND OWNER.	Source of Analyses	Geological Formation	COMPOSITION (PER CENT.) Calcium Carbonate	Magnesium Carbonate	Iron and Aluminum Oxids	Sand, clay, etc. (Insoluble)	Other minerals	Undetermined	Total	Burning Tests
LANCASTER COUNTY.										
Chickies: Haldeman, South Quarry........	II	Ordovician	54.75	44.20	.52	.44	.05	.04	100.00	
Chickies: Haldeman, North Quarry, (light br. gray stone)........	II	Ordovician	55.10	43.60	.30	.85	.10	.05	100.00	
Chickies: Haldeman, North Quarry (dark blue gray stone)........	II	Ordovician	53.52	43.52	.87	1.93	.08	.08	100.00	
Chickies: Haldeman, North Quarry (brownish gray stone)........	II	Ordovician	50.34	41.14	.73	7.70	.14	....	100.05	
Columbia: Chestnut Hill Iron Ore Co.....	II	Ordovician	86.00	7.00	....	7.00	....	....	100.00	
Lancaster: McHain & Bro.'s Quarry......	IV	Ordovician	59.52*	36.92*	....	3.20	....	.86	100.00	
Lapps: H. L. Rhoads(?)........	I	Ordovician	60.70	35.12	2.44	1.96	....	....	100.28	
Marietta: B. F. Hiestand(?)........	I	Ordovician	52.57	44.59	.71	1.52	....	.61	100.00	
Mt. Joy: Ezra Zercher........	I	Ordovician	70.41	12.85	.96	13.38	.28	2.12	100.00	
Pequea Valley: S. D. McHorin........	IV	Ordovician	....	36.00	....	....	....	....	....	
Rheems: High C. Lime and Stone Co......	III	Ordovician	97.95	.98	.11	....	....	.96	100.00	
Windom: E. H. Hess........	I	Ordovician	63.73	4.04	4.04	28.39	....	.80	100.00	
LAWRENCE COUNTY.										
Croton, (2 m. N.): Moffit's Quarry......	II	Vanport	94.78	1.37	1.19	2.08	.38	.20	100.00	
Lowellville, (near): G. W. Johnston Limestone Co........	III	?	89.35	....	3.92	5.05	.16	1.52	100.00	
Mount Jackson, (2 m. N. W.): McCord's Quarry........	II	Vanport	95.77	1.10	.63	1.97	.26	.27	100.00	
New Castle: Green's, Morgan's and Johnson's Quarries........	II	Vanport	93.34	1.46	1.56	3.07	.41	.16	100.00	
New Castle: New Castle Portland Cement Co........	III	?	91.07	.72	2.52	3.50	1.05	1.14	100.00	
Wampum: Shinn & Bros.' Quarry........	II	Vanport	94.21	1.73	.80	2.79	.45	.02	100.00	
Wampum: Crescent Portland Cement Co., (top)........	II	Vanport	87.90*	1.57*	1.98	4.50	3.01	1.04	100.00	
Wampum: Crescent Portland Cement Co., (middle)........	II	Vanport	89.56*	.88*	1.98	4.14	3.83	....	100.39	
Wampum: Crescent Portland Cement Co., (bottom)........	II	Vanport	92.93*	.90*	1.42	2.31	2.33	.11	100.00	

* Recalculated.

LEBANON COUNTY.									
Annville: J. A Bechman	II	Ordovician	94.78	1.37	1.19	2.08	.38	.20	100.00
Annville: Walter T. Bradley	IV	Ordovician	95.10	3.96	1.37	1.07	....	....	100.50
Annville: Annville Stone and Lime Co.	II	Ordovician	98.93	.57	.26	.18	....	.06	100.00
Annville: J. B. Millard & Son	III	Ordovician	98.55	.63	.41	.50	....	....	100.09
Annville: J. B. Millard & Son	III	Ordovician	97.11	1.07	.66	.83	....	.33	100.00
Annville: J. B. Millard & Son	III	Ordovician	97.41	.96	.63	.87	....	.13	100.00
Annville: J. B. Millard & Son	III	Ordovician	96.68	1.65	.64	.96	....	.07	100.00
Annville: J. B. Millard & Son	III	Ordovician	95.68	2.79	.72	.87	....	....	100.06
Annville: J. B. Millard & Son	III	Ordovician	96.07	1.81	.82	1.15	....	.15	100.00
Annville: J. B. Millard & Son	III	Ordovician	96.92	1.48	.65	.86	....	.09	100.00
Annville: J. B. Millard & Son	III	Ordovician	98.36	.91	.24	.39	....	.10	100.00
Heilmandale: Dr. Heilman(?)	I	?	76.13	1.30†	2.12	20.12	....	.33	100.00
Lebanon: Lackawanna Steel & Iron Co.	III	Ordovician	65.18*	28.35*	1.90†	5.00	.01	....	100.44
Lebanon: Elam Seigrist	III	Ordovician	90.91	6.70	.60	1.86	....	....	100.07
Meyerstown: General Crushed Stone Co.	III	Ordovician	93.21*	1.68*	.78	.92	3.41*	....	100.00
Meyerstown: General Crushed Stone Co.	III	Ordovician	92.89*	1.60*	1.06	1.16	3.29*	....	100.00
Meyerstown: General Crushed Stone Co.	III	Ordovician	93.98*	2.33*	1.02	.82	1.85*	....	100.00
Meyerstown: General Crushed Stone Co.	III	Ordovician	95.20*	1.68*	1.06	.64	1.42*	....	100.00
Meyerstown: General Crushed Stone Co.	III	Ordovician	95.73	.75	.90	2.52	....	.10	100.00
Palmyra: Annville Stone Co.	III	Ordovician	97.00	.98	.26	.45	....	1.31	100.00
Palmyra: Annville Stone Co.	III	Ordovician	99.44	Trace	....	.27	....	.29	100.00
Palmyra: Annville Stone Co.	III	Ordovician	98.78	.68	....	.30	....	.24	100.00
Palmyra: Annville Stone Co.	III	Ordovician	99.22	Trace	....	.65	....	.13	100.00
Palmyra: Annville Stone Co.	III	Ordovician	99.37	Trace	....	.31	....	.32	100.00
Palmyra: Palmyra Quarry Co.	III	Ordovician	98.11	1.00	.35	.50	....	.04	100.00
Palmyra: Walter T. Bradley	III	Ordovician	98.44	....	....	....	....	1.56	100.00
Richland: John K. Dierwechler	I	Ordovician	92.77	1.44	.58	5.69	....	....	100.48
West Meyerstown: Calcite Quarry Co.	III	Ordovician	98.38	.61	.49	.51	....	.01	100.00
West Meyerstown: Calcite Quarry Co.	III	Ordovician	97.00	....	....	.87	.05	2.08	100.00
LEHIGH COUNTY.									
Alburtis: Thomas Iron Co., (bluish gray stone)	II	Ordovician	51.92	41.07	....	5.65	.02	1.34	100.00
Alburtis: (Crystalline stone)	II	Ordovician	47.89	39.59	....	11.26	.05	1.21	100.00
Alburtis: Ruth's Quarry	II	Ordovician	48.25*	36.87	1.18†	12.13	.38	1.19	100.00
Allentown: Wenner Quarry; hard stone	II	Ordovician	51.56	35.22	.14†	10.75	2.31	.02	100.00
Allentown: Wenner Quarry; soft stone	II	Ordovician	86.04	4.59	.06†	8.40	1.27	....	100.36
Allentown: Wenner Quarry; crumbled stone	II	Ordovician	50.08*	43.15	2.36†	3.08	1.02	.31	100.00
Allentown: Wenner Quarry; Fresh stone thereunder	II	Ordovician	52.47*	42.80	.70†	1.12	1.65	1.26	100.00
Allentown: Ehrig's Quarry	I	Ordovician	52.86*	43.45*	1.79*	1.90*	....	....	100.00
Allentown: Geo. F. Erich	III	Ordovician	54.43	42.75	1.60	2.00	....	....	100.78
Allentown: Geo. F. Erich	III	Ordovician	53.43	44.20	1.50	1.32	....	....	100.45
Allentown: Ziegenfuss, Heiberger & Co.	III	Ordovician	54.00	44.75	....	1.25	....	....	100.00
Allentown: Ziegenfuss, Heiberger & Co.	III	Ordovician	53.71	44.69	.96†	....	.64	....	100.00
Allentown: Ziegenfuss, Heiberger & Co.	III	Ordovician	53.56	44.87	....	1.09	....	.48	100.00
Catasauqua: F. Eberhart	III	Ordovician	57.34	27.91	5.65	2.16	.01	6.93	100.00

* Recalculated.

† Aluminum oxid only.

Analyses of Pennsylvania Limestones, by Counties—(Cont.)

LOCATION AND OWNER.	Source of Analyses	Geological Formation	COMPOSITION (PER CENT.) Calcium Carbonate	Magnesium Carbonate	Iron and Aluminum Oxids	Sand, clay, etc. (Insoluble)	Other minerals	Undetermined	Total	Burning Tests.
LEHIGH COUNTY—(Cont.)										
Catasauqua: F. Eberhart	III	Ordovician	55.16	38.58	7.41	1.85	....	....	103.00	
Catasauqua: D. Wilson	III	Ordovician	90.00	3.50	1.50	5.00	.01	....	100.01	
Coplay: Eckert Quarry, average	II	Ordovician	72.65	3.79	5.74	14.20	3.37	.25	100.00	
East Allentown: Trexler Bros	III	Ordovician	55.89	27.16	0.74	1.49	....	5.72	100.00	
Guth's Station: Thomas Iron Co.	II	Ordovician	56.22	31.20	.30†	10.98	1.75	....	100.45	
Ironton: Ironton R. R. Co.	II	Ordovician	83.63	5.46	....	7.85	3.01	.05	100.00	
Limeport, (¼ m. N.): E. G. Erney	I	Ordovician	49.86	37.57	2.60	10.18	....	....	100.21	
Macungie: J. D. Christman	III	Ordovician	46.61	43.21	1.28	6.82	....	2.08	100.00	
Trexlertown: Kohler's	II	Ordovician	51.60	32.92	....	13.49	.10	1.89	100.00	
Trexlertown: Frantz's	II	Ordovician	48.63	40.41	....	9.24	.04	1.68	100.00	
Trexlertown: Israel Stettler	III	Ordovician	86.50	1.21	2.30	7.22	....	2.77	100.00	
LYCOMING COUNTY.										
Brookside: Owner unknown	I	Loyalhanna	50.48	2.65	....	44.33	....	2.54	100.00	
Brookside: Owner unknown	I	Loyalhanna	58.98	....	....	33.03	....	7.99	100.00	
Chippewa: Reeder's Quarry; upper bed	I	Lewistown	90.71	.84	.80	5.85	....	1.80	100.00	
Chippewa: Reeder's Quarry; middle bed	I	Lewistown	95.36	.87	.53	2.34	....	.90	100.00	
Chippewa: Reeder's Quarry; lower bed	I	Lewistown	94.82	.50	.58	3.87	....	.23	100.00	
Chippewa: McConnell's Quarry; upper bed	I	Lewistown	91.79	1.09	.48	3.25	....	3.39	100.00	
Jersey Shore: Wilson Quarry	II	Lewistown	70.59	1.74	4.66	21.68	.07	1.33	100.00	
Jersey Shore: Ferguson Quarry	II	Lewistown (?)	60.96	30.69	1.33	6.96	.26	....	100.20	
Jersey Shore: Bailey Quarry	II	Lewistown	72.16	20.30	1.60	5.57	.43	....	100.06	
Lime Bluff: Armstrong Quarries; up. bed	I	Lewistown	94.46	1.70	.58	2.77	....	.49	100.00	
Lime Bluff: Armstrong Quarries; mid. bed	I	Lewistown	91.61	1.36	.83	5.08	....	1.12	100.00	
Lime Bluff: Armstrong Quarries; lower bed	I	Lewistown	95.23	2.34	.43	2.19	....	....	100.19	
Montoursville: I. F. Kalb	I	Lewistown	89.28	....	....	2.71	....	8.01	100.00	
Montoursville: Cement (?) rock	I	Lewistown	77.67	....	....	16.00	....	6.33	100.00	
Northern Twps.: Precise locality unknown	* I	Loyalhanna	37.36	2.64	8.51	50.07	.59	.83	100.00	
Northern Twps.: Precise locality unknown	I	Loyalhanna	47.73	3.21	3.26	45.15	.06	.50	100.00	
Roaring Branch, (4 m. N. W.): Doney's	I	Loyalhanna	58.72	2.86	6.16	32.37	....	.39	100.00	Lime, red; slakes rather well.
Roaring Branch, (3 m. W.); John Austin	I	Loyalhanna	47.28	1.31	9.90	41.51	....	....	100.00	
Trout Run: Owner unknown	I	Loyalhanna	59.19	2.72	6.45	31.84	....	....	100.20	Lime, red-brown; slaked fairly well.
MIFFLIN COUNTY.										
Allenville: Joshua Peachy	I	Ordovician	90.34	5.25	.53	3.35	....	.55	100.00	
Belleville: D. Campbell	II	Ordovician	97.65	1.18	.43	.76	.18	....	100.15	

* Recalculated.

† Aluminum oxid only.

MIFFLIN COUNTY—(Cont.)									
Belleville: A. Campbell	II	Ordovician	81.18	13.40	1.25	4.53	.19	....	100.55
Belleville: Bottom of "chazy" bed	II	Ordovician	70.21	24.41	1.06	4.05	.13	....	100.16
Belleville: Greenwood ore bank	II	Ordovician	54.28	36.11	1.42	8.01	.41	....	100.23
Granville: Mrs. Wm. Hays (?)	I	Lewistown (?)	83.57	1.57	3.88	9.21	....	1.77	100.00
Milroy: National Limestone Co.	III	Ordovician	95.75	2.03	1.36	1.69	....	....	100.83
Milroy: National Limestone Co.	III	Ordovician	96.24	2.86	.61	.33	....	....	100.04
Newton Hamilton: I. J. Miller (?)	I	Lewistown (?)	25.61	3.36	....	59.30	....	11.73	100.00
Paintville: W. H. Goss (?)	I	Lewistown (?)	96.22	1.82	....	2.07	....	....	100.11
MONROE COUNTY.									
Bossardville: T. M. Hiller	II	Bossardville Upper	94.39	1.53	.70	2.85	.17	.46	100.00
Bossardville: T. M. Hiller	II	Bossardville Upper	87.90	1.90	2.10	7.90	....	.20	100.00
Decker's Ferry: Owner unknown	II	Stormville Lo.	97.10	1.50	.30	1.20	.06	....	100.16
Decker's Ferry: Owner unknown	II	Peth Stone	38.90	23.70	7.60	27.40	.24	2.16	100.00
Decker's Ferry: Owner unknown	II	Peth Stone	36.40	17.50	11.00	28.70	....	6.40	100.00
East Stroudsburg: Owner unknown	II	Corniferous	89.00	.90	.40	9.90	.16	....	100.36
Experiment Mills: Owner unknown	II	Bossardville Lower	73.43	2.65	2.97	20.24	....	.71	100.00
Kunkeltown: Amazon L. Shaffer	I	?	85.02	2.27	4.80	7.90	....	.01	99.99
Middle Smithfield Twp.: DeWitt's	II	Peth Stone	37.70	25.30	6.30	29.70	.09	.91	100.00
Middle Smithfield Twp.: DeWitt's	II	Peth Stone	37.10	26.40	7.10	28.50	....	.90	100.00
Middle Smithfield Twp.: Van Aucken's	II	Bossardville Upper	82.70	2.80	1.40	11.90	....	1.20	100.00
Middle Smithfield Twp.: Van Aucken's	II	Bossardville Upper	93.30	1.40	.80	4.20	....	.30	100.00
Middle Smithfield Twp.: Van Aucken's	II	Bossardville Upper	93.90	1.30	.70	3.90	....	.20	100.00
Middle Smithfield Twp.: Van Aucken's	II	Bossardville Upper	88.80	2.30	.70	7.60	....	.60	100.00
Poxono Island: Owner unknown	II	Poxono	90.20	4.30	1.10	3.60	.77	.03	100.00
Poxono Island: Owner unknown	II	Poxono	89.40	3.30	1.30	5.90	.78	....	100.68
Smithfield Twp.: Le Barr's	II	Stormville Lower	90.80	1.20	.70	6.80	.11	.39	100.00
Smithfield Twp.: Le Barr's	II	Stormville Lower	89.80	1.50	.90	7.00	.18	.62	100.00
Smithfield Twp.: Le Barr's	II	Stormville Lower	92.30	1.40	.60	5.50	.23	....	100.03
Smithfield Twp.: Brown's	II	Bossardville Upper	94.30	2.10	.50	3.00	....	.10	100.00
Smithfield Twp.: Brown's	II	Bossardville Upper	92.20	2.20	1.10	4.30	....	.20	100.00
Stormville: Owner unknown	II	Stormville	74.90	2.20	2.60	19.70	....	.60	100.00
Stormville: Owner unknown	II	Peth Stone	43.80	29.70	6.30	17.60	....	2.60	100.00

Analyses of Pennsylvania Limestones, by Counties—(Cont.)

LOCATION AND OWNER.	Source of Analyses	Geological Formation	COMPOSITION (PER CENT.) Calcium Carbonate	Magnesium Carbonate	Iron and Aluminum Oxids	Sand, clay, etc. (Insoluble)	Other minerals	Undetermined	Total	Burning Tests
MONTGOMERY COUNTY.										
Bridgeport: Merion Lime and Stone Co.	III	Ordovician	55.00	45.00	....	....	....	....	100.00	
Bridgeport: Chas. Warner Co.	III	Ordovician	55.70	41.97	.72	1.58	....	.03	100.00	
Conshohocken: On river	II	Ordovician	40.27	31.24	....	28.49	....	....	100.00	
Conshohocken: O'Neill Stone Co.	III	Ordovician	55.05	41.01	....	2.07	.01	1.86	100.00	
King of Prussia: Millard, Schwoyer & Co., (blue)	IV	Ordovician	98.16	1.08*	.17†	.77	....	....	100.18	
King of Prussia: Millard, Schwoyer & Co., (dark blue)	IV	Ordovician	97.71	1.68	.16†	.58	....	....	100.13	
Norristown: Merion Lime & Stone Co.	III	Ordovician	55.45	43.97	.30†	.20	....	.08	100.00	
Norristown: W. W. Potts	III	Ordovician	96.64	2.85	....	.51	....	....	100.00	
Norristown: W. W. Potts	III	Ordovician	61.98*	33.94	....	1.32	2.76	....	100.00	
Norristown: W. W. Potts	III	Ordovician	99.02	.48	.23	.21	.01	.05	100.00	
Norristown: W. W. Potts	III	Ordovician	92.08	6.60	.57	.75	.01	....	100.01	
Norristown: W. W. Potts	III	Ordovician	59.91	38.43	.64	.97	....	.05	100.00	
Norristown: W. W. Potts	III	Ordovician	88.00	11.57	.18	.27	....	....	100.02	
Norristown: W. W. Potts	III	Ordovician	61.92	35.51	1.60	.97	....	....	100.00	
Norristown: W. W. Potts	III	Ordovician	84.84	14.17	.33	.64	....	.02	100.00	
Norristown: Rambo Lime Co.	III	Ordovician	54.04	45.51	.20	.25	....	....	100.00	
Norristown: Rambo Lime Co.	III	Ordovician	53.49	45.76	.45‡	.20	....	.10	100.00	
Plymouth Meeting: E. J. Lavino & Co.	III	Ordovician	54.06	44.63	....	....	....	1.31	100.00	
Plymouth Meeting: E. J. Lavino & Co.	III	Ordovician	54.10	44.53	.80	.56	....	.01	100.00	
Port Kennedy: Todd & Son (Dolomite)	II	Ordovician	53.19	45.45	.90	.25	.02	.19	100.00	
MONTOUR COUNTY.										
Danville, (near): Mrs. K. Maus	I	Lewistown(?)	73.32	16.15	....	10.27	....	.26	100.00	
Danville, (near): Mrs. K. Maus	I	Lewistown(?)	65.96	23.69	....	9.93	....	.42	100.00	
Danville, (near): Mrs. K. Maus	I	Lewistown(?)	80.86	8.06	....	10.61	....	.47	100.00	
Danville, (near): Mrs. K. Maus	I	Lewistown(?)	75.46	8.55	....	11.25	....	4.74	100.00	
NORTHAMPTON COUNTY.										
Chain Dam: Robert J. Clark	III	Ordovician	54.11	38.72	2.99‡	1.59		2.59	100.00	
Easton: Easton Lime Co.	III	Ordovician	53.64	41.31	1.64	3.11	....	.30	100.00	
Redington: C. H. Ziegenfuss & Co.	III	Ordovician	93.01	4.11	.96	1.50	.08	.34	100.00	

* Recalculated. † Aluminum oxid only. ‡ Iron oxid only.

NORTHUMBERLAND COUNTY.										
Dewart: M. A. Nicely	I	Lewistown (?)	80.21	.90	....	18.89	....	....	100.00	
Georgetown: J. J. Yeager	I	Lewistown (?)	91.79	1.75	4.29	1.54	.63	....	100.00	
Northumberland, (2 m. N.): A. J. Seller, (bottom bed)	I	Lewistown (?)	94.33	1.59	.50	3.10	....	.48	100.00	
Northumberland: A. J. Seller, Middle bed	I	Lewistown (?)	96.01	1.06	.62	1.66	....	.65	100.00	
Northumberland: A. J. Seller, Upper bed	I	Lewistown (?)	87.73	3.36	1.50	6.23	....	1.18	100.00	
PERRY COUNTY.										
Mahanoy Valley: Still's Quarry (dark blue)	II	Lewistown	71.73	7.62	2.55	15.72	.03	2.35	100.00	
Mahanoy Valley: Still's Quarry (bluish gray)	II	Lewistown	89.64	1.82	1.21	6.53	.02	.78	100.00	
Millerstown Station, (¼ m. S.): Foot of ridge.	I	Lewistown	85.37	5.10	1.88	5.66	....	3.99	100.00	Lime, red. white; slakes to fine powder; swell, 2-fold.
Millerstown Station: Top of ridge	I	Lewistown	91.84	2.84	1.88	4.18	....	....	100.74	Lime, white; slakes readily; swell, almost 2-fold.
Millerstown Station: 30 ft. below top	I	Lewistown	90.69	4.17	1.30	3.90	....	....	100.06	Lime, gy. white; slakes more slowly, but fine.
Newport: Comminuted shells in siliceous matrix	II	Onondaga?	60.21	1.66	5.38	31.52	.15	.08	100.00	
Newport: Comminuted shells in siliceous matrix	II	Onondaga?	49.18	1.82	5.76	41.94	.12	1.18	100.00	
Newport: Comminuted shells in siliceous matrix	II	Onondaga?	33.48	1.97	8.30	53.81	.19	2.25	100.00	
SNYDER COUNTY.										
Beaver Springs: Gray stone	I	Lewistown?	71.15	1.60	....	21.85	....	3.90	100.00	
" Nearly 30 ft. from creek	I	Lewistown?	34.80	....	....	40.28	....	24.92	100.00	
" Mud, below quarry, upper part	I	Lewistown?	45.26	4.22	6.28	40.74	....	3.50	100.00	
" Mud, below quarry, middle part	I	Lewistown?	56.04	3.64	4.60	33.30	....	2.42	100.00	
" Mud, below quarry, lower part	I	Lewistown?	42.15	3.19	5.40	45.95	....	3.31	100.00	
Selinsgrove: Hessinger's Quarry	I	Corniferous?	92.80	1.64	1.01	4.17	....	.38	100.00	
Selinsgrove: Selinsgrove Church Quarry	I	Corniferous?	87.06	1.83	.77	9.22	....	1.12	100.00	
SOMERSET COUNTY.										
Davidsville: Trevormor's Quarry	II	Johnstown	90.54	2.13	.26	3.85	2.69	.03	100.00	
Elk Lick: Keystone Lime Co.	III	?	86.62	6.15	1.82	4.64	.12	.65	100.00	
Friendensburg, (1¼ m. S. S. E.): Reitz's Quarry	II	Johnstown	86.78	2.91	2.97‡	6.04	1.26	1.36	100.00	
Haskin's Run: D. Rodgers	II	Johnstown	52.94	16.06	4.44†	17.77	6.16	2.63	100.00	
Jenner's Cross-Roads: Blain's Quarry, up. bd	II	Johnstown	92.30	1.48	36†	3.95	2.00	....	100.09	
" Blain's Quarry; middle bed	II	Johnstown	54.32	23.09	1.63†	12.02	9.89	....	100.95	
" Blain's Quarry; lower bed	II	Johnstown	69.26	13.77	.40†	10.76	5.69	.12	100.00	
" P. G. Berkey's Quarry	II	Elk Lick	89.52	5.33	.22†	2.50	2.45	....	100.02	
Listie: Listie Mfg. Co.	III	?	92.12	2.35	2.00	3.53	.02	....	100.02	

† Aluminum oxid only. ‡ Iron oxid only.

Analyses of Pennsylvania Limestones, by Counties—(Cont.)

LOCATION AND OWNER.	Source of Analyses	Geological Formation	COMPOSITION (PER CENT.) Calcium Carbonate	Magnesium Carbonate	Iron and Aluminum Oxids	Sand, clay, etc. (Insoluble)	Other minerals	Undetermined	Total	Burning Tests
SOMERSET COUNTY—(Cont.)										
Meyersdale, (1 m. W.): Yoder's Quarry....	II	Elk Lick	55.59	14.22	2.89†	19.80	7.35	.15	100.00	
" (¾ m. N. W.): Saylor Hill Quarry	II	Fishpot	69.16	15.53	1.87†	9.73	4.08	.13	100.00	
" (¾ m. W.); Saylor Hill Quarry	II	Benwood	85.73	5.10	2.87	6.22	.34	....	100.26	
" Keystone Coal & Mfg. Co.'s Quarry	II	Benwood	72.62	12.61	3.21	9.18	.41	1.97	100.00	
Salisbury: Flickering's Quarry...........	II	Little Pittsburgh.	64.71	2.16	1.70†	20.66	13.51	....	102.74	
" (2½ m. S. W.): Bushey Quarry.	II	Redstone	86.62	6.15	1.82	4.04	.28	1.09	100.00	
" (1 m. N.); J. M. Hayes.......	II	Fishpot	74.80	6.73	1.55†	11.51	5.55	....	100.14	
Scalp Level, (¾ m. W.): J. Weaver......	II	Johnstown	50.16	18.49	11.60‡	13.36	.63	5.76	100.00	
Somerset, (3½ m. S. E.): Zimmerman's Qu.	II	Johnstown	63.97	4.24	4.39‡	24.78	1.26	1.36	100.00	
Stoystown: Wilt's Quarry...............	II	Johnstown	88.14	1.85	.84†	5.64	2.74	1.29	100.00	
Sipesville: J. J. Pile..................	II	Johnstown	79.48	10.22	3.69‡	4.97	.49	1.35	100.00	
Ursina, (¾ m. N.): Pittsburg Coal & Coke Co.'s Quarry........................	II	Elk Lick	90.80	2.74	1.99	3.74	.81	.42	100.00	
SULLIVAN COUNTY.										
Forksville: (R. D. 2)....................	I	Chemung?	93.56	1.17	....	5.27	....	....	100.00	
Millview: R. H. Luda's property; upper bed	II	Chemung?	80.39	5.65	5.20	5.24	4.02	....	100.50	
Millview: R. H. Luda's property; lower bed.	II	Chemung?	69.00	5.39	5.87	17.85	3.25	....	100.36	
Millview: R. H. Luda's property..........	I	Chemung?	87.95	1.00	....	49.39	....	11.66	100.00	
SUSQUEHANNA COUNTY.										
Lathrop: Geo. W. Schoonover(?)..........	I	Cherry Creek?	50.60	....	....	31.17	.03	18.20	100.00	
TIOGA COUNTY.										
Liberty: C. U. Maneval(?)...............	I	?	53.82	2.82	4.96	35.80	2.67	.43	100.00	Lime, reddish; slakes fine, rather quickly; swell, 3-fold.
Liberty: C. U. Maneval(?)...............	I	?	56.29	2.10	4.16	33.80	3.45	.20	100.00	Lime similar to foregoing in appearance and slake.
Liberty: G. C. Roat.....................	I	?	....	....	5.30	54.28	....	41.47	100.00	
Mann's Creek: Wilson....................	II	?	51.80	....	....	42.00	....	6.20	100.00	Lime, red; slakes quickly and fairly fine; swell, 2⅓-fold.
Morris: A. C. Comstock(?)...............	I	?	52.78	1.97	4.62	38.41	1.80	.42	100.00	
Morris: G. T. Atkins....................	I	?	....	....	5.41	39.47	....	55.12	100.00	Lime, dirty white; slaked readily and well.
Wellsboro, (2 m. S.): E. J. Trettle, ("real limestone.").........................	I	?	68.82	....	....	....	1.44	29.74	100.00	

† Aluminum oxid only.

‡ Iron oxid only.

TIOGA COUNTY—(Cont.)										
Wellsboro: E. J. Trettle (soil from next field)	I	?	....	....	....	90.45	.11	8.08	100.00	"Burns to a slow-slaking lime."
Wellsboro, (4 m. W.): I. Derbyshire(?)...	I	?	75.49	2.27	6.40	18.04	....	2.80	100.00	
UNION COUNTY.										
Swengle's (near): C. Dorman(?).........	I	?	92.49	2.08	.82	4.80	....	.36	100.00	
West Milton: Geo. P. Miller..............	I	Clinton?	96.01	1.36	.44	1.50	.28	.39	100.00	
West Milton: Geo. P. Miller..............	I	Clinton?	95.57	2.10	.79	1.59	....	....	100.05	
West Milton: Geo. P. Miller..............	I	Clinton?	87.77	4.99	1.06	6.71	....	....	100.53	
WAYNE COUNTY.										
Exact locality unknown..................	II	Cherry Creek	64.40	1.82	1.15	28.80	.10	3.73	100.00	
Exact locality unknown..................	II	Cherry Creek	19.80	3.52	8.90	65.47	.19	2.12	100.00	
Exact locality unknown..................	II	Cherry Creek	17.70	1.59	4.48	75.22	.06	1.00	100.00	
Exact locality unknown..................	II	Cherry Creek	11.20	1.66	5.00	80.95	.08	1.11	100.00	
WASHINGTON COUNTY.										
Boyce, (2 m. W.): G. B. Rowly, (top)...	I	?	13.45	2.41	....	76.80	....	7.30	100.00	
Boyce, (2 m. W.): G. B. Rowly, (middle).	I	?	76.03	6.63	....	9.75	....	7.59	100.00	
Boyce: G. B. Rowly, (bottom)..........	I	?	70.61	7.94	....	12.99	....	8.46	100.00	
Canonsburg, (1 m. N.): Owner unkn'n; Up.	II	Benwood (Lower Div.)	68.84	14.65	3.31[*]	18.30	.34	....	100.44	
" Owner unknown; middle.....	II	Benwood (Lower Div.)	48.82	20.62	3.52[†]	22.52	4.28	.28	100.00	
" Owner unknown; lower......	II	Benwood (Lower Div.)	47.08	28.53	7.51[*]	15.75	.46	.67	100.00	Lime, yellow; does not slake or heat with water.
Clarksville, (1 m. N. E.): C. A. Williamson?	I	?	47.93	28.61	8.26	17.52	....	2.68	100.00	
Murdocksville: E. Armor...............	I	?	95.92	1.05	1.40	2.00	....	....	100.31	Lime, dirty white; slaked readily and fairly fine.
North Strobane Twp.: Pollrick's Quarry..	I	?	82.46	2.27	2.50	12.06	....	.71	100.00	Lime, gray; slaked quickly and well; swell, little
North Strobane Twp.: Pollrick's Quarry..	I	?	78.81	3.59	3.92	13.10	....	.48	100.00	Lime, gray; slaked more slowly than preceding.
North Strobane Twp.: Pollrick's Quarry..	I	?	82.20	2.05	2.64	11.54	....	2.05	100.00	Lime like that from foregoing sample.
Somerset Twp.: Dr. Shaner.............	II	Benwood	47.75	30.24	5.68	14.92	.34	1.24	100.00	
Washington: Owner unknown...........	II	Upper Washington..	72.87	3.81	2.93	17.38	.52	2.09	100.00	
WESTMORELAND COUNTY.										
Calumet: Penn Lime Product Co........	III	?	82.14	9.12	3.52	5.00	.55	....	100.33	
Herminie: West Westmoreland Stone & Lime Co..........................	III	?	94.20	2.16	1.33	2.03	....	.28	100.00	
Herminie: Westmoreland Stone & Lime Co.	III	?	93.21	1.40	1.70	2.92	.78	....	100.01	
Kelley's Station, (½ m. N. W.): Wining & Cuisan..........................	II	Freep't Up.	91.98	1.66	1.52	4.01	.25	.58	100.00	
Salina: Kier Bros.....................	II	Freep't Up.	94.64	1.14	2.72	.99	.10	.41	100.00	Lime, yellow; slaked slowly and imperfectly; swell, 1-3.
Youngwood: A. Getany.................	I	?	66.66	2.47	5.36	22.24	....	3.27	100.00	

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[*] Iron as ferrous carbonate, with alumina.

[†] Aluminum oxid only.

Analyses of Pennsylvania Limestones, by Counties—(Cont.)

LOCATION AND OWNER.	Source of Analyses	Geological Formation	COMPOSITION (PER CENT.) Calcium Carbonate	Magnesium Carbonate	Iron and Aluminum Oxids	Sand, clay, etc. (Insoluble)	Other minerals	Undetermined	Total	Burning Tests
YORK COUNTY.										
Dillsburg: Welty's Quarry	II	Mesozoic	80.22*	10.82*	2.40‡	14.01	1.21	....	?	
Dillsburg: Welty's Quarry	II	Mesozoic	78.91*	13.14*	2.32‡	10.89	.18	....	?	
Dillsburg: Welty's Quarry	II	Mesozoic	83.87*	7.95*	1.69†	10.46	.60	....	?	
Dillsburg: Welty's Quarry	II	Mesozoic	76.63*	6.25*	2.68‡	18.58	1.14	....	?	
Dillsburg: Welty's Quarry	II	Mesozoic	78.38*	6.01*	5.09‡	27.01	2.38	....	?	
Dillsburg: Delaware Product Co.	III	?	70.00	5.00	16.00	....	....	3.00	100.00	
Emigsville: Emigsville Quarry Co.	III	Ordovician	98.35	1.41	.13	.19	....	....	100.08	
Emigsville: Emigsville Quarry Co.	III	Ordovician	96.35	2.08	.31	1.13	.05	.08	100.00	
Hanover: Bittinger & Eberly	II	Ordovician	83.12	8.23	.03	.53	4.33	.56	100.00	
Hanover: John R. Bittinger	I	Ordovician	95.36	....	....	1.03	.86	3.25	100.00	
Hanover: John R. Bittinger	I	Ordovician	98.62	....	....	.26	.16	.96	100.00	
Hanover: Stacey & Wilson	III	Ordovician	99.74	.40	.08	.06	....	....	100.28	
Hellam: Stacey & Wilson	III	Ordovician	93.14	6.50	.14	.12	....	.10	100.00	
Menges Mills; Sprenkel Quarry (greenish st.)	II	Ordovician	65.70*	10.30*	2.03‡	16.65	6.94	.51	100.00	
Menges Mills: Sprenkel Quarry (bluish st.)	II	Ordovician	68.71*	1.67*	7.45‡	18.21	5.10	1.70	100.00	
Rutterstown: A. J. Bair	I	Ordovician	88.56*	2.08*	....	8.06*	....	1.85*	100.00	
Seitzland: Owner(?)	II	Archaean	93.87	.96	.43‡	4.30	....	.44	100.00	
Thomasville: Thomasville Stone & Lime Co.	I	Ordovician	90.10	.96	.03	.10	8.25	.56	100.00	
Thomasville: Thomasville Stone & Lime Co.	III	Ordovician	98.79	.82	.18	.21	....	....	100.00	
Thomasville: Thomasville Stone & Lime Co.	III	Ordovician	99.08	34	.08	.47	....	.08	100.00	
Wrightsville: Kerr Bros	II	Ordovician	66.79	31.46	2.07†	5.65	.67	....	?	
Wrightsville: Kerr Bros	I	Ordovician	98.85	.16	1.44	.56	....	....	100.51	
Wrightsville: Kerr Bros	I	Ordovician	94.12	1.85	2.36	.46	....	1.21	100.00	
Wrightsville: Kerr Bros	I	Ordovician	91.48	.90	.60	6.42	....	.60	100.00	
Wrightsville: Kerr Bros	I	Ordovician	78.57	1.09	1.46	19.35	....	....	100.47	
Wrightsville: Kerr Bros	I	Ordovician	80.96	9.62	3.49	4.91	....	1.02	100.00	
Wrightsville: Kerr Bros	I	Ordovician	97.10	2.60	....	8.00	....	....	103.70	
Wrightsville: B. Frank Beard	III	Ordovician	95.29	1.93	....	.48	....	2.35	100.00	
Wrightsville: B. Frank Beard	III	Ordovician	99.08	.84	.08	.47	....	.08	100.00	
Wrightsville: B. Frank Beard	III	Ordovician	94.53	3.18	1.80	.49	....	....	100.00	
Wrightsville: B. Frank Beard	III	Ordovician	93.32	3.32	3.10	.26	....	....	100 00	
Wrightsville: Steacy & Wilson Co.	III	Ordovician	54.26	44.51	.66	.56	....	.01	100.00	
Xenia: Owner(?) (greenish stone)	II	Ordovician	62.35	6.32	7.53	20.06	....	3.74	100.00	
York: Lowell M. Palmer	I	Ordovician	98.20	1.93	.68	.23	....	....	101.04	
York: Palmer Lime & Cement Co.	III	Ordovician	98.21*	2.12*	.88	.30	....	....	101.01	
York: Palmer Lime & Cement Co.	III	Ordovician	100.21*	.81*	.19	.20	....	....	100.91	
York: York Valley Lime Co.	III	Ordovician	97.27	1.98	.17	.23	.09	.26	100.00	
York: York Valley Lime Co.	III	Ordovician	97.67	1.72	.16	.18	....	.32	100.00	
York: J. E. Baker & Co.	I	Ordovician	79.91	12.65	2.54	4.56	....	.84	100.00	

* Recalulated.   † Aluminum oxid only.   ‡ Iron oxid only.

The large amounts of undetermined matter, noted in some cases, are chiefly such as moisture, organic matter, silica soluble in the acids used to bring the lime and magnesia into solution, sulphur, small amounts of potash, soda, and phosphoric acid, etc. In most cases, no attempt was made to determine these comparatively unimportant substances; though, in impure limestones, their sum total may form a considerable percentage of the limestone.

Commercial Limestone Products.

The station has analyzed, from time to time, a considerable number of samples, submitted by those interested as purchasers, and purporting to be representative of various commercial limestone products. These analyses are given in the following table. Owing to the private source of the samples, the Station does not vouch that each of these samples correctly represents the commercial product whose name it bore. The analyses are, however, published as representing substantially, the composition of the samples received, and, in a general way, the condition of the limestone products of the several commercial classes now sold on the Pennsylvania markets.

Owing to the indefinite meaning attached by many to the commercial names of the several limestone products in agricultural use, these names are here defined.

When limestone, which is chiefly composed of calcium carbonate (carbonate of lime, $CaCO_3$) is heated to red heat, its carbon dioxid (CO_2) splits off as a gas, leaving a white or nearly white solid of slightly greater volume than the original stone. This burned solid is *lime* (Calcium oxid, CaO). Magnesium carbonate (carbonate of magnesia, $MgCO_3$) is usually present in the limestone in larger or smaller amount. When the limestone is burned, the magnesium carbonate gives off carbon dioxid gas, and leaves the white solid *magnesia* (magnesium oxid, MgO). By appropriate chemical methods, the oxygen can be extracted from these oxids, leaving the respective metals, *calcium*, (Ca), a yellowish body of metallic luster, and *magnesium* (Mg), the white metal sold in ribbons or in powder. These metals are not, however, used as such for agricultural purposes.

When water is added to the lime (CaO), it is absorbed with much heat, and the lime swells and falls to a fine powder. In this condition, it is called *slaked lime*, or, when carefully made by the aid of machinery, *hydrated lime* (Calcium hydrate, $Ca(OH)_2$). Any magnesia in the lime tends likewise to form magnesium hydrate ($Mg(OH)_2$), but the change is slow, and little heat is manifested. Hence, highly magnesian limes slake slowly, are "cold-slaking," swell little or not at all, and sometimes do not fall to pieces.

When lime is exposed to the air, it slowly absorbs moisture and becomes hydrated. It also absorbs, but more slowly, carbon dioxid, (carbonic acid) from the air, and re-carbonates; that is, returns in part to its original state of combination as calcium carbonate. In the case of the magnesia, the process is much slower, and the carbonic acid product is a basic carbonate ($Mg(OH)_2$, $Mg\ CO_3$). Lime thus slaked by air exposure is said to be air-slaked. The interior of large lime heaps does not re-carbonate for years.

In addition to the determinations corresponding to the chemical nature of the several classes of commercial limestone products, the lime and magnesia value of each product, in the condition in which it was received, is given. This value determines the final utility of the materials for soil neutralization. Of course, the pure lime (or magnesian lime) has the highest value; while those products containing large proportions of inert matters, carbonic acid, or water (free or combined), must have correspondingly lower value.

ANALYSES OF LIMESTONE PRODUCTS, ETC.

ANALYSES OF LIM

STATION NO.†	NAME AND ADDRESS OF MANUFACTURER OR DEALER	BRAND NAME.	Calcium carbonate, CaCo$_3$
	Ground or Crushed Limestone		
48,189	American Lime and Limestone Co., Bellefonte, Pa. Remarks—All passed 80-mesh seive.	Ground limestone	89.48
48,770	American Lime and Limestone Co., Bellefonte, Pa. Remarks—Fineness: Over 1-20 in., 2.74 per cent.; 1-20-1-40 in., 16.78 per cent.; 1-40-1-60 in., 11.64 per cent.; under 1-60 in., 69.18 per cent.	Ground, 40-mesh	97.85
48,771	American Lime and Limestone Co., Bellefonte, Pa. Remarks—Fineness: 1-20-1-40 in., .48 per cent.; 1-40-1-60 in., .41 per cent.; under 1-60 in., 99.16 per cent.	Ground, 60-mesh	90.76
50,068	Bessemer Limestone Co., Youngstown, O.		84.65
50,288	Bessemer Limestone Co., Youngstown, O.		79.91
49,280	Branchton Limestone Co., Union City, Pa.	Ground limestone	84.00
49,244	Caledonia Marl Co., Caledonia, N. Y.	Lime carbonate	87.18
47,952	Caledonia Marl Co., Caledonia, N. Y.	Agricultural lime	89.27
50,066	Carbon Limestone Co., Youngstown, O.		92.58
49,248	Haserot Canneries Co., Cleveland, O. Remarks—Weighs 30 lbs. per bushel. By-product of acetone manufacture.	Horsehead Brand Carbonate Lime	92.52
49,784	Haserot Canneries Co., Cleveland, O. Remarks—Weighs 30 lbs. per bushel. By-product of acetone manufacture.	Horsehead Brand Carbonate Lime	91.80
48,622	E. H. Hess, Windom, Pa.	Ground limestone	63.71
48,080	Lowell M. Palmer, York, Pa. Remarks—All passed seive of 1-80 in. mesh.	Crushed limestone	98.20
49,733	Manufacturer unknown		97.51
49,622	Manufacturer unknown		85.31
49,226	Manufacturer unknown		82.38
48,419	Manufacturer unknown		93.91
	Oyster Shells		
49,739	Baltimore Lime Products Co., Baltimore, Md.	Oyster shells (natural)	89.59
50,189	?	Ground oyster shells	84.86
	Lime		
49,221	American Lime and Limestone Co., Tyrone, Pa.	Lime	42.41
III	Annville Stone Co., Easton, Pa.	Lime	....
III	C. F. Bacon, Salunga, Pa.	Lime	....
48,404	A. J. Bair, Rutterstown, Pa.	Lime	4.87
III	Beaver Valley LimeCo., Elwood City, Pa.	Lime	....
50 155	Bessemer Limestone Co., Youngstown, O.	Lime	....
III	John R. Bittinger, Bittinger, Pa.	Lime	....
III	Walter T. Bradley, Palmyra, Pa.	Lime	....
49,068	Buffalo Fertilizer Co., Buffalo, N. Y. Remarks—Is not lime, but marl or crushed limestone.	"Agricultural lime"	80.16
49,274	Climax Lime and Stone Co.	Lime	14.66
III	Geo. W. Cumbler, Steelton, Pa.	Lime	....
49,223	Ehrig, Allentown, Pa.	Lime	20.43
41,943	Fostoria White Lime Co., Fostoria, O.	Lime	28.45
48,296	W. H. Ghaner, Benore, Pa.	Lime (Farm-burned)	....
20,487	B. F. Heckert, Dalmatia, Pa.	Lime	16.05
49,534	Luther Keller, Portland, Pa.	Lime (Wood-burned)	10.27
49,222	Kelley Island Lime & Transport Co., Cleveland, O.	Lime	12.73
48,401	LeGore Combination Lime Co., LeGore, Md. Remarks—Represented to writer 96.0-97.6 per cent. lime.	Lime	7.66

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†From E. F. Burchard, "The Production of Lime in 1911," U. S. Geol. Survey.

ONE PRODUCTS, ETC.

CHEMICAL COMPOSITION (PER CENT.)										
CaO.	Calcium hydrate Ca (OH)$_2$.	Magnesium carbonate, MgCo$_3$	Magnesium oxid, MgO.	Magnesium hydrate, Mg(OH)$_2$	Iron and aluminum oxids $F_2O_3+Al_2O_3$	Sand, clay, etc. (Acid insoluble)	Other minerals.	Undetermined.	Total.	Lime & magnesia value.
...	.....	3.09	.....	.....	.96	6.54	.13	.....	100.20	51.59
...	.....	.64	.....	.....	.....	1.05	.....	.46	100.00	55.11
...	.....	2.78	.....	.....	.....	6.01	.....	1.50	100.00	52.13
...	.....	.98	.....	.....	2.53	11.46	.....	.38	100.00	47.87
...	.....	1.05	.....	.....	2.21	15.98	.....	.85	100.00	45.25
...	.....	8.96	.....	.....	2.42	6.85	.....	2.77	100.00	48.93
...	.....	1.74	.....	.....	1.50	5.59	.....	8.99	100.00	49.65
...	.....	.....	.....	.....	.....	.67	.....	10.06	100.00	49.99
...	.....	.82	.....	.....	1.30	4.60	.....	.75	100.00	52.21
...	.....	6.67	.....	.....	.37	.53	.....	.....	100.09	55.00
...	.....	1.80	.....	.....	2.05	.40	.....	3.95	100.00	52.27
...	.....	4.04	.....	.....	8.04	28.39	.....	.80	100.00	37.62
....	.....	1.93	.....	.....	.68	.23	.....	.....	101.04	55.91
....	.....	.46	.....	.....	.68	.59	.....	.76	100.00	54.82
....	.....	2.83	.....	.....	1.54	9.30	.....	.76	100.00	48.88
....	.....	2.99	.....	.....	1.44	11.67	.....	1.51	100.00	47.57
....	.....	1.45	.....	.....	.58	.46	.....	3.60	100.00	58.28
....	.....	.46	.....	.....	1.75	6.93	.....	1.27	100.00	50.39
....	.....	1.03	.....	.....	1.41	6.23	.....	6.47	100.00	48.01
1.65	47.20	.....	1.25	.....	1.08	5.20	.....	1.26	100.00	62.87
6.96	.....	.....	.94	.....	5.10	1.46	.....	.....	104.60	97.90
5.00?	.....	.....	.....	.....	.....	5.00	.....	.....	100.00	95.00
5.49	75.89	.....	1.28	.....	.....	10.69	.....	1.78	100.00	66.98
6.39	.....	.....	1.09	.....	8.92	4.53	.....	4.05	100.00	87.48
7.94	.....	.....	.58	.....	2.01	11.60	38.52*	.....	100.72	48.52
2.00	.....	.....	8.55	.....	.03	.53	4.28	.....	100.34	95.55
5.80	.....	.....	.....	.....	.....	.....	.....	4.20	100.00	95.80
....	.....	7.48	.....	.....	1.66	5.29	4.48	.98	100.00	48.44
0.81	89.88	.....	.70	.....	4.10	9.30	.....	.55	100.00	69.90
5.00	.....	.....	10.00	.....	.....	8.00	.....	2.00	100.00	95.00
....	88.85	.....	13.74	21.76	2.48	2.64	.....	.10	100.00	69.63
3.61	42.06	.....	.....	.....	.....	9.90	.....	15.97	100.00	51.37
....	90.21	.....	.....	2.25	.....	5.39	.....	2.15	100.00	69.83
2.41	.....	.....	1.34	.....	6.80	2.43	1.00	.....	100.00	82.72
....	45.70	.....	4.82	27.93	5.22	6.16	.....	.....	100.10	64.48
....	59.49	.....	19.15	6.26	.28	.25	.....	1.84	100.00	75.68
7.99	73.38	.....	3.28	.....	.....	5.68	.....	2.04	100.00	71.05

*Loss on ignition=moisture (free and combined), carbon dioxid, and organic matter.

STATION NO.†	NAME AND ADDRESS OF MANUFACTURER OR DEALER	BRAND NAME.	Calcium carbon-ate, CaCO
48,402	LeGore Combination Lime Co., LeGore, Md....... Remarks—Represented to writer 96.0-97.6 per cent. lime.	Lime	8.7
48,403	LeGore Combination Lime Co., LeGore, Md....... Remarks—Represented to writer 96.0-97.6 per cent. lime.	Lime	7.8
III	George Martz, Shamokin, Pa..................	Lime	....
49,921	Merion Lime and Stone Co., Norristown, Pa.....	Lime	16.2
III	Oakes Bros., Volant, Pa......................	Lime	....
49,288	Ohio & Western Lime Co., Marion, O...........	Lime	6.0
49,275	Ohio & Western Lime Co., Marion, O...........	Lime	1.9
III	Paxtang Quarry Co., Paxtang, Pa..............	Lime	....
III	Paxtang Quarry Co., Paxtang, Pa..............	Lime	....
49,224	Pennsylvania Limestone Co., Water Street, Pa...	Lime	14.9
48,783	A. H. Pheil, Chambersburg, Pa.................	Lime	14.0
50,101	Reading Quarry Co., Temple, Pa...............	Lime	....
48,629	Rochester Lime Co., Rochester, N. Y...........	Lime	....
48,630	Rochester Lime Co., Rochester, N. Y...........	Lime	....
20,488	Ryter & Ryan, Halifax, Pa....................	Lime	....
III	Thomasville Stone and Lime Co., Thomasville, Pa.	Lime	....
III	Vulcanite Limestone Co., Hummelstown, Pa......	Lime	....
47,539	Walton Quarries, Harrisburg, Pa...............	Lime	45.2
III	Charles Warner Co., Bridgeport, Pa............	Lime	....
III	Charles Warner Co., Bridgeport, Pa............	Lime	....
III	Chas. Warner Co., (Whiteland Plant), Dewalt, Pa.	Lime	....
III	C. Warner Co.,(Cedar Hollow Plant), Dewalt, Pa.	Lime	....
49,021	C. Warner Co.,(Cedar Hollow Plant), Dewalt, Pa.	Lime	21.
III	Chas. Warner Co., Plymouth Meeting, Pa........	Lime	....
III	White Rock Quarries, Pleasant Gap, Pa.........	Lime	....
III	White Rock Quarries, Pleasant Gap, Pa.........	Lime	....
50,075	White Rock Quarries, Pleasant Gap, Pa.........	Lime forkings.................	1.
48,994	Woodville Lime & Cement Co., Woodville, O.....	Lime	13.
	Ground Lime:		
49,701	? Chambersburg, Pa.........	Ground lime..................	3.
49,703	Thomasville Stone & Lime Co., Thomasville, Pa.	Ground lime..................	1.
	Hydrated Lime:		
41,658	?	Hydrated lime................	17.
48,140	American Lime & Limestone Co., Bellefonte, Pa..	Hydrated lime................	22.
48,081	Lowell M. Palmer, York, Pa...................	Hydrated lime................	3.
49,310	Paragon Lime & Limestone Co., Bloomsburg, Pa.	Hydrated lime................	11.
	Air-Slaked Lime:		
47,879	Cassidy Kiln, Ashville, Pa................... Remarks—From center of frozen 1 bu. heap, exposed for several weeks.	Air-slaked lime.....	12.
48,732	? Berwyn, Pa.......... Remarks—From heap weathered for 10 years.	Air-slaked lime....	24.
48,907	? Remarks—From heap 5 years old.	Air-slaked lime..............	23.
49,020	Annie Wertz Miller, Berwyn, Pa.... .... Remarks—Represents 4 in. depth of heap exposed for 10 years.	Air-slaked lime.	27.
49,284	? Butler Pa.	Air-slaked lime..............	35.

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† III From E. F. Burchard, "The Production of Lime in 1911," U. S. Geol. Survey.

TONE PRODUCTS, ETC.—Cont.

CHEMICAL COMPOSITION (PER CENT.)										
CaO.	Calcium hydrate $Ca(OH)_2$.	Magnesium carbonate, $MgCo_3$	Magnesium oxid, MgO..	Magnesium hydrate, $Mg(OH)_2$	Iron and aluminum oxids $F_2O_3+Al_2O_3$	Sand, clay, etc. (Acid insoluble)	Other minerals.	Undetermined.	Total.	Lime & magnesia value.
.06	81.73	.....	1.29	.....	.....	3.82	.....	1.40	100.00	71.07
.58	64.58	.....	4.38	.....	.....	3.33	.....	2.29	100.00	70.20
.00?	.....	.....	2.35	.....	.....	.....	.....	.....	100.35	100.35
...	62.44	.....	10.78	.....	4.75	1.63	3.68	.52	100.00	67.10
1.92	.....	.....	.77	.....	9.24	1.04	.03	3.00	100.00	72.69
.69	10.03	.....	24.54	.....	1.25	1.22	.....	1.22	100.00	91.21
.86	9.49	.....	38.92	.....	.54	.25	.....	.99	100.00	95.05
.08	.....	.....	1.05	.....	.21	2.15	.12	.....	100.56	98.08
.00	.....	.....	Trace	.....	.22	.76	.12	.....	100.10	90.00
...	53.24	.....	.....	6.28	5.92	17.53	.62	1.48	100.00	52.99
.39	68.52	.....	1.44	.....	1.60	5.60	.....	.....	100.56	70.53
.44	.....	.....	15.97	.....	3.60	2.21	2.42	.....	100.64	92.41
.89	.....	.....	38.42	.....	.45	.39	.....	4.85	100.00	94.31
.28	.....	.....	39.24	.....	.76	.29	.....	2.18	100.00	96.52
.78	.....	.....	3.01	.....	5.63	1.03	1.13	6.47	100.00	85.74
.52	.....	.....	1.25	.....	.28	.....	.....	.....	100.00	99.77
.00	.....	.....	2.00	.....	1.50	1.50	.....	.....	100.00	97.00
.59	42.05	.....	1.61	.....	.....	2.80	.....	4.68	100.00	62.87
.33	.....	.....	37.87	.....	1.35	2.95	.....	.....	100.00	95.70
.33	.....	.....	38.45	.....	2.57	3.82	.....	.....	100.17	93.78
.12	.....	.....	38.94	.....	.84	.84	.92	.14	100.00	96.06
.64	.....	.....	38.56	.....	1.16	2.04	1.62	.34	100.00	95.20
...	31.28	.....	.....	38.35	1.92	2.85	2.15	1.68	100.00	62.37
.18	.....	.....	39.03	.....	1.79	3.03	.....	.....	100.03	95.21
.34	.....	.....	1.05	.....	.38	.50	.....	.....	100.27	99.39
.28	.....	.....	.24	.....	.20	.34	.....	7.94	100.00	91.52
2.28	10.40	.....	.87	.....	4.79	9.92	.....	.47	100.00	81.71
...	50.66	.....	21.76	12.54	.40	.66	.....	.58	100.00	76.30
2.95	30.33	.....	3.40	.....	4.76	4.82	.....	.....	100.00	81.78
.82	31.35	.....	.96	.....	.03	.10	.....	.....	100.19	91.58
...	42.07	.....	27.88	7.89	.....	.....	.40	3.83	100.00	75.22
...	64.30	.....	.....	.....	1.93	1.19	7.70	1.42	100.00	61.91
...	95.23	.....	.....	.85	.77	.13	.78	.....	100.70	74.28
6.98	69.48	.....	1.03	.65	3.70	7.12	.....	.46	100.00	66.88
...	77.36	.....	.....	1.26	2.50	4.06	2.23	.....	100.00	66.46
...	26.75	.....	.....	20.39	11.40	14.76	2.67	.....	100.00	48.21
...	.....	.....	.....	.....	.....	6.24	.....	.....	.....	.....
...	37.82	.....	5.67	11.34	3.84	12.19	.....	1.41	100.00	57.66
...	26.44	.....	17.79	14.13	2.10	2.50	.....	1.34	100.00	67.56

on ignition = Moisture (free and combined), carbon dioxid, and organic matter.

These data suggest the following notes:

(1) Of the crushed limestone samples here represented, all are low in magnesia. The inert matters present range from .91 to 32.32 per cent.; the lime and magnesia (CaO_2 and MgO) values, from 37.62 to 55.91 per cent.

(2) The oyster shells here represented contain much more earthy impurity than would be expected from analyses of pure shells. These earthy matters have doubtless been accidentally introduced, but they lower the lime and magnesia value to 50 per cent or less.

(3) The analyses of the commercial "limes" exhibit a wide range of conditions for these materials, with correspondingly great range in the lime and magnesia values, viz.: 48.44 to 100.35 per cent. The analyses taken from the U. S. Geological Survey bulletin, represent "stone" or "freshburned lime;" those submitted to the Experiment Station, were more or less slaked. In some cases, they were doubtless "hydrated limes," instead of "lime," as they were represented to be, a fact easily explained by the popular confusion of the names of these products.

Of the 46 samples of lime here represented, 16 contained 10 per cent or more of magnesia. These magnesian limes came chiefly from southeastern Pennsylvania, and from central and northern Ohio.

The quantities of carbonate of lime present in many of these lime samples are far beyond those that could be produced by air-slaking in a short time. Their probable explanation is the presence of "cores" or underburnt stone. The case of the "agricultural lime" containing 80.16 per cent. of carbonate of lime, and having a lime and magnesia value of only 48.44 per cent., well illustrates the confusion and loss to the buyer which must follow the application of the name "agricultural lime" to anything except lime proper.

(4) The ground limes here represented are low in carbonate, but contain 6 to 7 per cent. of hydration water; that is, between one-third and one-fourth of the lime present is slaked.

(5) Of the few "hydrated limes" submitted as such, three out of four indicate the addition, in considerable amount, of ground cores to the product. The slaking was quite complete in each case, that is, the calcium oxid was quite fully hydrated.

(6) The air-slaked limes from old heaps well illustrate the slow rate at which the interior portions of lime heaps re-carbonate.

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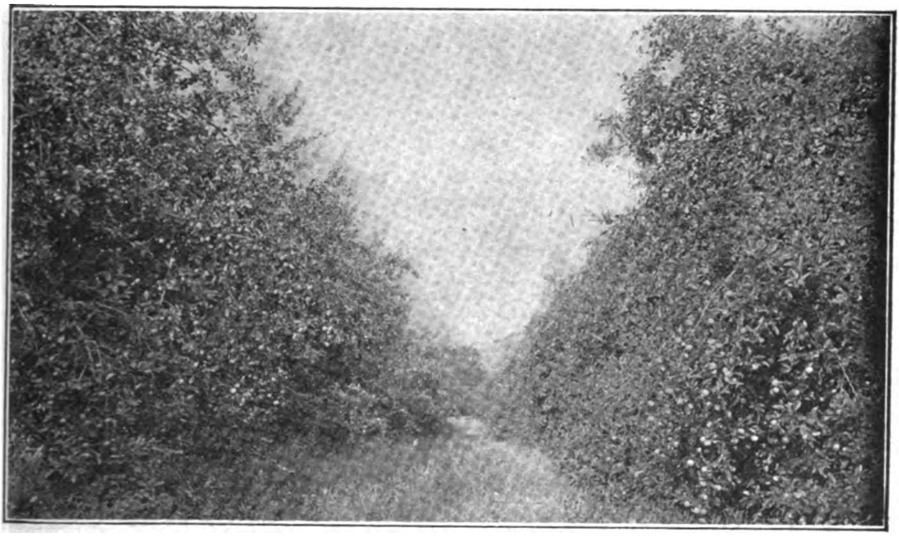
The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 128



View in a Pennsylvania Commercial Orchard

THE APPLE IN PENNSYLVANIA:

VARIETIES, PLANTING AND GENERAL CARE

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
FEBRUARY, 1914.

AGRICULTURAL EXPERIMENT STATION THE PENNSYLVANIA STATE COLLEGE

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 128

THE APPLE IN PENNSYLVANIA:

VARIETIES IN PLANTING AND GENERAL CARE

By JOHN P. STEWART

Extensive experiments and observations bearing upon apple production in Pennsylvania have been in progress under the writer's direction since 1907. The present bulletin is an outgrowth of this work. Without going into experimental details, which are reported elsewhere, it aims to present concisely the principal facts needed by the average grower in the starting and maintenance of an orchard in the highest efficiency possible in the light of most recent results.

The general adaptability of the state to apple production is apparent in the fact that it is located practically in the center of the leading apple-producing district of America, as indicated by the Federal census. It is also apparent in the fine product and marked success of many growers in various parts of the state, and in the high yields obtained in certain of our experimental treatments, a number of which show an average production of 500 to 600 bushels per acre annually over five or six year periods. In addition, the general nearness to market and the frequent availability of suitable sites at comparatively low cost should make this industry especially attractive to those properly inclined and fitted to follow it.

Location and Soil.

The first requisite of a successful commercial orchard is a suitable location. This requires a good topography, the right kind of soil, a convenient water supply, and ready access to market or to satisfactory shipping points. A good topography is one which is moderately sloping or rounding and is enough higher than the surrounding country to give good drainage of cold air and water. A grade of 2 or 3 per cent. is usually sufficient to drain off the cold air satisfactorily, especially if there is a deeper outlet near, and too much of a slope is always objectionable, especially on erosive soils. A difference in local elevation, of as little as 20 or 30 feet, often results in the success or failure of a crop, as a result of the selective action of frosts at blossoming time. The direction of the slope is of little or no importance in this state, though it often needs some consideration in regions farther north and possibly farther south.

The right kind of soil for apples is determined chiefly by the subsoil. This should be comparatively open and porous for at least a foot below the surface, and preferably for a depth of three feet or more. Below this the soil or other strata should be compact enough to prevent the moisture from sinking beyond the reach of capillary action, but should not be so tight as to subject the trees to the danger of "wet feet." The character of the subsoil can readily be determined with the aid of a good spade or soil auger.

The soil of the immediate surface is of less importance, as good orchards occur on all classes of surface soils from dense clays to light sands. For apples, the writer prefers a rather intermediate soil for the first 6 or 8 inches, preferably a loamy soil with a moderate admixture of sand, and more or less interspersed with gravel. In general also, the soils derived from ironstone, sandstone, or other non-calcareous formations, are usually preferable to the limestone soils, at least from the viewpoint of the quality and earliness of the fruiting. A good general test of fitness may also be found in the presence of old and productive trees under similar conditions in the neighborhood.

As a rule the price of a soil is little or no criterion of its value for apple production. This is because the price is ordinarily based on the farm's value in producing the general agricultural crops, except in the more advanced and definite fruit-growing sections. In such sections the price of suitable land is usually much higher than in the regular farm-crop sections, though the latter may often contain many equally satisfactory sites for orchards. Also the apparent fertility of a soil, as indicated by its production of the general crops, is usually of very little value in determining its fitness for fruit.

Purchase and Handling of Nursery Stock.

In ordering trees, one should emphasize especially the necessity of their being true to name, thoroughly healthy, properly matured, and full of life. By the latter is meant that the trees should be entirely dormant but in strong living condition when received by the grower, and not be shrivelled or discolored, nor show any other evidence of premature or improper handling. The union of the graft or bud should be good, and the roots should be entirely free from all evidence of the woolly-aphis or of the crown-gall or hairy-root disease. The general appearance of these unfortunately common troubles is shown in the accompanying Figures 1 and 2. The particular form of propagation,—whether whole or piece root,—is immaterial so far as growth in the orchard is concerned[1], and the same is true of the place or region in which the tree is produced, so long as it is sound and of the right variety for the locality involved.

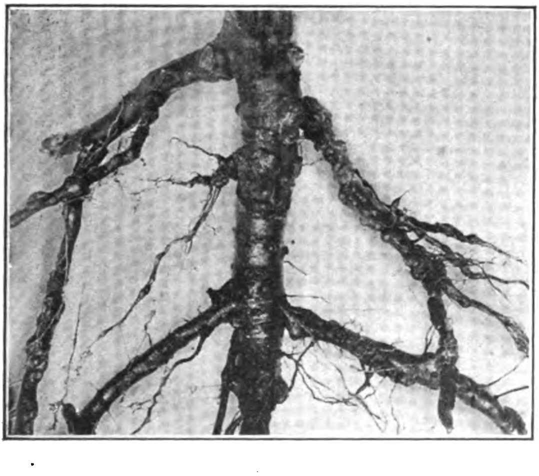

Figure 1.—Woolly Aphis Injury on Young Apple Roots. All such trees should be discarded.

One-year-old trees of good size,—neither stunted nor overgrown,—are usually best and in no case should they be older than two years from the bud or graft. The advantages of the one-year trees are that they usually cost less, they are more readily shipped and transplanted, those fit for sale are sure to be strong growers, and their heads can be formed as desired. If older trees are preferred, however, care should be taken to see that their limbs are properly separated and well distributed around the trunk and are located approximately at the heights desired.

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[1] Data on this may be found in our Annual Report for 1907-8, pp. 198-200; and also in Kansas Bulletins 65 and 106, Illinois Bulletin 21, and Alabama Bulletin 98.

It is best to deal directly with responsible nurseries and to order early, submitting requirements to a number of firms for bids. The trees may be held at the nursery subject to order at planting time. Where the winters are not too severe, fall planting is advisable, otherwise plant in the spring as soon as the ground is fit, though it may be done later if the trees are kept satisfactorily dormant. When received the trees should be examined and "heeled in" at once. The roots should be shortened back to about six or eight inches, and those broken or bruised should be removed with a smooth cut above the place of injury. This pruning is often done before heeling in.

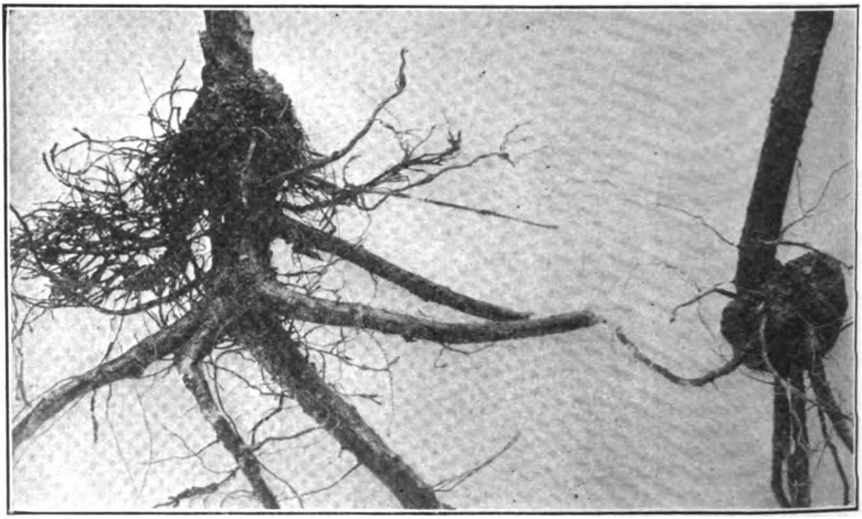

Figure 2.—Crown-Gall and Hairy-Root on Apple, and Crown-Gall on Peach. Two phases of the same disease caused by certain bacteria. Such trees should not be planted.

The heeling in may be done by plowing two or more deep furrows, preferably east and west, so that the trees can be leaned toward the south or southwest, at an angle of 30 to 40 degrees, and thus escape sun-scald. They should be completely unpacked, with all straw or other material liable to attract mice removed, and then be laid along the furrow in a single row or layer. The roots and a third or more of the tops should then be covered immediately with dirt, which must be packed especially thoroughly around the roots. This covering may be done at least partly with the plow and successive layers can be laid when needed. The place selected for this purpose should be well drained, and where there is likely to be damage from mice the whole area should be surrounded with furrows or ridges of dirt, with all packing material and grass or other unnecessary vegetation removed.

Laying Out the Orchard and Planting

The two leading plans for laying out orchards are the square or rectangular and the hexagonal or the equilateral triangular. The hexagonal plan permits of more trees to the acre at a given distance apart, or conversely it allows about 15½ per cent. more space for each tree with the same number per acre. The square plan allows more space for intercropping. It is also somewhat preferable in connection with fillers since it permits their removal in two distinct stages, and it is less confusing to one in the orchard. With either plan one can try out from two to four varieties, side by side, for a number of years and then remove all but one variety and leave it standing at the desired distance apart. The arrangement necessary to accomplish this is shown in Figures 3 and 4.

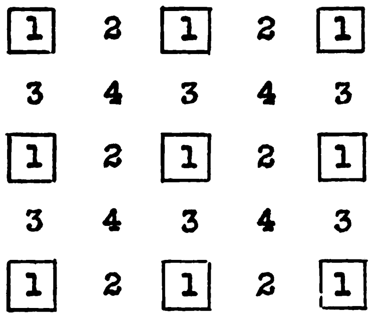

Figure 3.—The Square Plan. Showing arrangement for fillers or for testing four varieties.

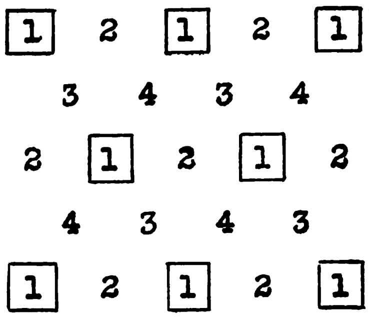

Figure 4.—The Hexagonal Plan. Showing arrangement for fillers or for testing four varieties.

Two varieties are more readily compared by the square plan, using positions 1 and 4 of the figure for this comparison, and planting regular fillers in the other positions. This arrangement is one of the very best, even when one already knows just what variety is wanted for the permanent trees. In such cases he can use position "1" for the permanents, position "4" for the semi-permanents, and then have the remaining positions for the more temporary fillers such as peaches, if they are to be used.

With any of these plans, if fillers are used, it is well to allow from 40 to 45 feet for the permanents,—which naturally leaves the intermediate trees at half those distances,—and even 50 feet may not be too much for some varieties on especially favorable soils. The number of trees per acre, in the square or rectangular arrangement, can be found by multiplying the number of feet the trees are apart by the number of feet between the rows, and using this product to divide 43,560,—the number of square feet in an acre. Thus for a 20-foot square planting we have 20x20=400; and 43,560÷400=108, which is the number of trees per acre. To find the number of trees per acre in the hexagonal arrangement, find the number allowed by the square method at the distance specified and add 15%, or for more exact work add 15.47%. At 20 feet apart the more exact process results in 125 trees per acre, which is the correct number for the hexagonal arrangement.

The hexagonal plan can be laid out most readily with the aid of a couple of light wires or chains, such as ordinary dog chains. One end of each chain or wire is fastened securely to an iron ring, about two or two and one-half inches in diameter, and a similar ring is fastened to the free end of each. When stretched out these chains must be exactly the same length, and they should just reach over stakes set at the distance desired for the trees. Stakes about one inch in cross-section and 15 to18 inches long, with the upper 6 or 8 inches dipped in whitewash, are very satisfactory. After the first row is staked out accurately, one man and a couple of boys can readily locate the balance of the trees with the device just noted. By placing the end rings over adjacent stakes in the new row established and drawing the chains tight on the middle ring, the position of the first tree in the next row is indicated by the latter ring, and all the remaining trees can be located similarly.

The square arrangement can be laid out fairly well with a plow, making deep furrows for the rows, and then dragging a chain across them to indicate the position of the trees. If greater accuracy is desired, it can be secured by using a wire of about 10 or 12 gauge, preferably galvanized and long enough to reach the full length of the field. Upon this wire, at the exact distance desired for the trees, short pieces of wire, or similar bits of metal, should be wound very tightly or soldered to prevent slipping. With such a wire, the base line, side lines, and all other rows in the orchard can be readily located and staked out. The chain device noted above might also be used in laying out orchards on the square plan, after the base lines are established, but it would be necessary to have one of the chains exactly 1.41421 times as long as the other, with the length of the shorter chain corresponding to the distance between the trees. It is probable, however, that either the furrow or the "long wire" method just noted will usually be preferred for the square plan.

For special accuracy in alignment, a planting board is generally used. This is usually an inch board about 4 inches wide and 6 feet long, with a deep notch in the middle and shallower notches at the ends. The middle notch is fitted against the tree stake and pegs are driven in the notches at the ends. The board is then removed, the hole is dug, and on replacing the board between the pegs, the middle notch indicates the exact position for the tree.

Planting the Trees.—Success in tree planting is largely a matter of avoiding all unnecessary root-exposure, and thorough firming of the soil about the roots. The soil on the immediate surface, however, is better left rather loose, and it may well be banked up somewhat to reduce swaying, especially if the trees are large. An excellent means of encouraging growth is to soak the roots of the trees in water for several hours before planting, and then haul them along the rows in a barrel or tub partially filled with water, taking them out only as needed. Set trees 1 to 3 inches deeper than they stood in the nursery, placing the sides with heaviest roots toward the prevailing winds and leaning the trunks slightly toward the southwest to lessen danger of sun-scald.

As a rule, little or no fertilization is needed at planting time, and as a matter of fact, positive injury may result from an injudicious use of fertilizers at this time. If something is desired to assist the trees in starting, however, the best and safest material is undoubtedly a moderate mulch of strawy stable manure. Its benefits, moreover, are probably more often due to its mulching effect than to its slight addition of plant-food. Where the manure is not available, similar results can usually be secured from any other kind of a mulch, especially if aided by a moderate application of nitrogen and phosphates. The latter materials are perhaps best applied in the organic forms, such as dried blood and finely ground bone, though the nitrogen may also be obtained satisfactorily from nitrate of soda and probably from ammonium sulphate. A pound of the nitrate, or one and one-half pounds of the blood, together with a similar weight of the bone, should be ample for each tree, and it should be spread uniformly over the surface for a distance of at least two or three feet out from the tree. In no case should the fertilization be placed in direct contact with the roots, nor even directly within the tree holes, though there is no objection to working it into the surface soil with a harrow or rake, if so desired.

Forming the Heads and Pruning

If one-year old "whips" are used, the only pruning needed at planting time, beyond that already indicated for the roots, is to cut them off at the height desired. The latter depends on the height at which the head or general framework is expected to be formed. In general, a height of 25 to 30 inches is low enough for the lowest permanent limb to appear. Above this a further space of at least 12 to 15 inches should be allowed to permit the framework limbs to appear at sufficient distances apart. A total height of at least 40 inches is therefore about right for heading back the whips, provided their lateral buds are sound. If the whips are already lower than this, they may be left uncut and the heads can be formed when the new growth, either from the terminal or from a good vigorous lateral, reaches the proper height. When the lateral buds are not reliable, head the whips back to about 20 inches, and develop the head as above from a new shoot.

As to type of head, the open-center or vase-form top is now generally preferred for all varieties except possibly those that are especially inclined to droop or those needing special protection against splitting or breaking down under load. The latter difficulty can be much reduced in any type of tree by having at least 4 to 6 inches of space between the points of emergence of the framework limbs, or it can be eliminated entirely by a proper system of bracing within the top. Three limbs, properly chosen, are sufficient for the framework of a vase-form tree, and a greater number than this is generally a nuisance later. It is usually best to start with four or five, however, in order to provide for the accidents that so often occur, and also to retain a greater amount of foliage for the more rapid growth of the tree.

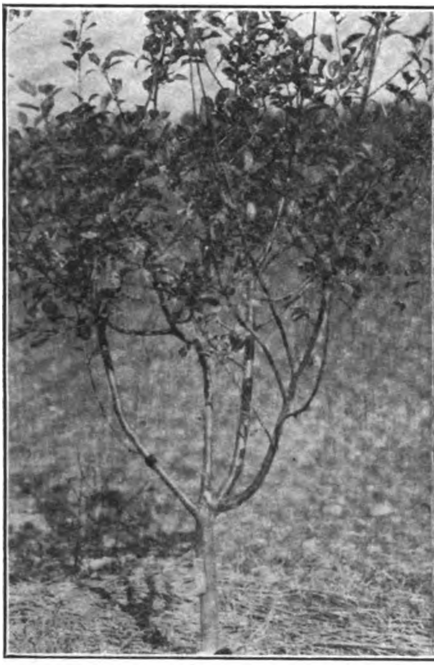

Figure 5.—A Poorly Headed Tree. Limbs poorly arranged and come out too close together.

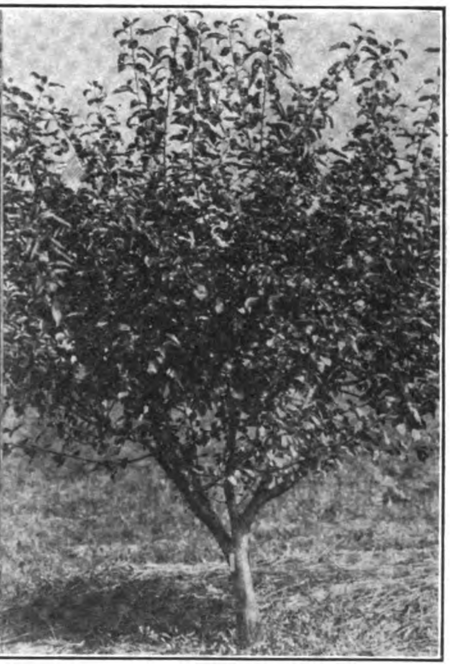

Figure 6.—Tree Well Headed. Would be better with more space between limbs.

The best time to select these limbs is probably during the early part of the first season's growth in the orchard. It is very easy at this time to go over the trees and select the 4 or 5 shoots that are desired for the permanent limbs, and then to rub off the remainder and pinch off the leader at the height preferred. In this selection special care should be taken to retain one or more vigorous limbs which point against the prevailing winds.

No further training is likely to be needed during the first season unless some of the limbs begin greatly outgrowing the others, in which case they should be pinched or headed back at their tips.

In the case of the older nursery trees, already branched, this selection of the framework limbs should be made at planting time, if satisfactory limbs are available; otherwise trim them again to a whip and develop the head as above from the first season's growth in the orchard.

Before growth starts in the second season, it is usually well to cut or head back at least some of the framework limbs, especially those making the strongest growth. This is to keep the top coming on more evenly, and the balance can also be improved by making the cuts slightly above good buds or limbs that point in the direction desired for the further growth. There is no particular length or number of buds to which this heading back should be done, and one and one-half to two-foot lengths are not too great, if all the limbs are sufficiently long to permit such lengths without disturbing the general balance.

Two good limbs, properly separated and pointing in the desired direction, are all that are needed from each of the framework limbs. They in turn should be selected early in the growth of the second season, and the other shoots should be rubbed off whenever they give evidence of developing into more than a spur or tuft of leaves. These secondary branches should be handled about as indicated above for the primary branches, and they in turn should be expected to produce two or possibly three branches for the general framework.

Later Pruning.—The training work just described practically completes the general formation of the heads, and it should be finished at least by the middle of the third season. After this the pruning should be reduced to a minimum until the trees come into bearing. A little thinning out of the denser places, removing of the crossing or unduly competing limbs, and an occasional heading back of the extra-vigorous branches that show signs of outstripping the others, are all that are needed and all that should be given if quick growth and early fruiting are desired. In fact with the later bearing varieties, such as the Spy and Baldwin, it may be well to adopt this policy by the middle of the second season or even earlier, in order to hasten their fruiting as much as possible[3].

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[3] It may be noted that the present advice differs materially from that commonly given. It is founded, however, on much practical experience and also on results of the long-continued experiments at Woburn, England. The latter show that all pruning, regardless of season, tends to delay fruiting and

After the trees begin bearing, somewhat stronger pruning may be done when needed, with the special objects of getting more light to the fruit and assisting the trees to carry their loads. The latter is accomplished by keeping the bearing wood low and well distributed through the tops, instead of out at the ends of poles as is so often the final result of ill-advised work. This later pruning may well begin in the tops of the trees and work downward,—a practice which frequently results in the retention of lower or more central limbs that otherwise might be removed.

Special care should always be taken to save the fruit spurs, and contrary to a prevalent notion the early blossoms should be left on, unless they appear in excessive numbers, in which case they should be thinned. As shown in our fertilizer experiments, there is no real antagonism between normal growth and fruiting, and the early formation of the bearing habit is highly desirable.

In all pruning the cuts should be made close to the parent branch, leaving no stubs, and all wounds of an inch or more in diameter should be covered with thick paint or melted grafting wax. The quickest healing of large wounds is probably obtained by pruning just about the time that growth starts, though it should be timed so as to avoid excessive "bleeding." Keep water sprouts off main limbs to avoid blight cankers.

Protection of Trees.

During the early years some protection must be given against mice, rabbits and borers. Galvanized wire screens for the former and "mounding and cutting-out" for the latter are the methods commonly employed, but a protective covering, such as thick, pure, oil-lead paint, without any turpentine or "dryer" in it, has certain advantages and has been satisfactorily used on apple but not on peach trees. The ordinary lime-sulphur concentrate, more or less mixed with sediment, is entirely safe for any of the common fruit trees, and it also makes a very satisfactory coating, if renewed sufficiently often. It can be readily applied either with a brush or a coarse spray nozzle, and the trunk should be thoroughly covered to a height of 18 inches or more.

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reduces both yield and growth,—the reduction being approximately in proportion to the severity of the pruning. Hence it should evidently be reduced to a minimum, though it cannot properly be omitted entirely if the tree is to be well formed. (See Report for 1907 of the Woburn Experimental Fruit Farm at Woburn, England).

Any covering is probably best applied about the middle or latter part of June, in order to be in best condition during the laying period of the borer. Partially girdled trees, if discovered in time, can usually be saved by preventing the drying out of the tissues. This may be done by a covering of grafting wax, lead paint, or sometimes by mounding deeply enough to keep moist.

Soil Management in the Orchard.

The four principal methods of handling the soil in an apple orchard are tillage, tillage and cover-crops, mulching and sod. Our experiments indicate that, for several years at least, the chief object of any cultural method is the conservation of moisture. They also indicate that a proper moisture supply is often the most important factor, especially in the early life of the tree. The best cultural method, therefore, is generally the one that is the best conserver of moisture.

From this viewpoint and also from that of tree growth, in our experiments, the mulching method has generally proved best, and sod alone has been poorest. By mulching we mean a sufficient application of grass, straw or other vegetation around the trees, to prevent largely or wholly the further growth of vegetation immediately over at least the greater portion of the root-feeding area. In young orchards, such a mulch can often be obtained from the growth between the trees. This is shown for one plant in Figure 7 and similar results can be obtained with other plants, preferably leguminous, or such materials as buckwheat straw, leaves or other cheap materials may be brought in from outside sources. Three tons per acre annually of fairly durable vegetation are ample to maintain a satisfactory mulch around bearing trees, and naturally less is needed for those younger.

The mulch method is especially suited to sites that are subject to erosion or to any orchard in which tillage is especially undesirable or difficult. Whenever it is used, however, special protection must be provided against mice, preferably by some of the measures mentioned above, and also by keeping the ground clear for at least six inches out from the trees. A good permanent cover to assist in maintaining the mulch may be secured from a combination of white and red clovers and hairy vetch, making the original seeding at the rates of about 3 pounds of the first, 10 pounds of the second and 20 pounds of the third per acre. Their permanence may often be materially increased by a good disking in the latter part of July or after a fair quantity of seed has matured.

Tillage Methods.—Wherever the mulching method is undesirable, or otherwise unavailable, either some form of tillage or proper fertilization should be regularly followed. In orchard tillage, the usual practice is to plow or thoroughly disk the soil in the spring, after which the ground is kept harrowed as often as needed to maintain a loose mulch of soil on the surface until about the middle of July. A depth of three inches is probably best for both operations, and anything deeper than four inches is distinctly objectionable over tree roots. At the close of the tillage season, a cover-crop—preferably leguminous—may be sown, or the soil may be left for the customary natural growth of grass and weeds. Crimson or red clover at the rate of about 20 pounds per acre, or a mixture of hairy vetch and rye at the rate of about 30 pounds of the former to a bushel of the latter, make very satisfactory cover-crops, and they may frequently show a profitable influence on the trees, especially where humus is needed. They should not be followed blindly, however, and their real influence can be roughly determined by leaving a typical portion of the orchard without any sown cover for comparison for three or more years.

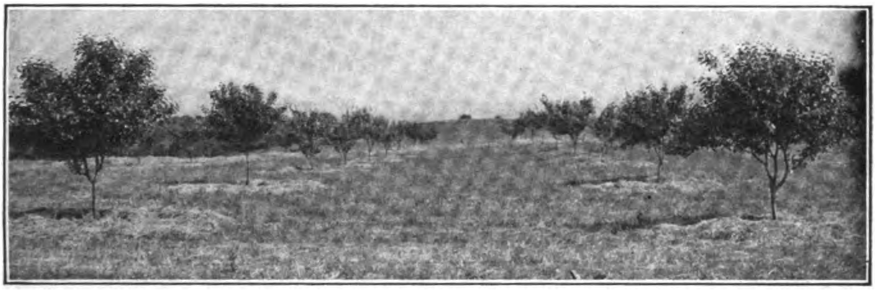

Figure 7.—Alfalfa Used as a Mulch and Permanent Orchard Cover. This system, with no tillage except that required for the alfalfa at the start, has given the best average growth, during the first five years, of any method tried in our orchard of 33 acres, which is devoted wholly to experiments.

The earliness of plowing and the length of the tillage season depends largely on the moisture conditions in the soil,—the more moisture present, the later the tillage may begin and the less of it will be required. Where soils are subject to washing, it may largely be prevented by tilling alternate interspaces every other year, thus giving each tree annual cultivation over half its roots. The chief implements needed for orchard tillage are a light gang plow, a disk or cutaway harrow on an extension frame, and good spring-tooth and smoothing harrows, or their equivalents. In addition to these, certain other implements may be useful at times, such as a good horse-hoe, a vineyard cultivator, a seeder, etc., but those named above are all that are really needed..

Intercrops and Fillers.—One advantage of the tillage system is the opportunity it often affords for the use of intercrops during the first few years. In general the best plants for the intercrop are early annuals that require tillage in the fore part of the season and do not require too late a stirring of the soil in their harvesting. From the standpoint of the trees, the least harmful are tilled, leguminous intercrops, such as peas or beans, because of their favorable nitrogen and moisture relations, but cabbage, cantaloupes, potatoes, or other hoed vegetables if accompanied by proper fertilization are often entirely satisfactory. All cereal intercrops are to be avoided, with the apparent exception of corn, for the first year. Its least harmful form is probably early sweet corn. Near the trees, however, either clean tillage or a satisfactory mulch should be maintained.

For fillers, peaches are undoubtedly the most profitable, if the soil and location are satisfactory for both them and the apples. Such conditions are somewhat rare, however, and since peaches are rather hard on the land and favor the development of the curculio, besides greatly complicating the orchard operations in general, it is usually considered better to use early bearing varieties of apples for at least part of this function. The fillers may be planted in the rows of one direction only, leaving the interspaces for vegetables or other tilled crops used in the combination indicated above. This plan is usually most satisfactory, if sufficient labor and markets are available. Both fillers and intercrops must be removed promptly, when the space is needed by the permanent trees, and the chief argument against their use is the failure to do this.

Fertilization.

In general, the need and value of soil fertilization is largely a local problem. As already indicated, young trees are less likely to respond to it than old. In any case, stable manure, at the rate of about 8 tons per acre annually, is as likely to prove profitable as any other treatment, either on sod or in connection with tillage. When it is not available, however, similar benefits can usually be secured with a commercial fertilizer carrying about 30 pounds of actual nitrogen, 50 pounds of actual phosphoric acid (P_2O_5), and 25 to 50 pounds of actual potash (K_2O), and the fertilizer is often quicker in action. These amounts are carried in 500 pounds of a 6-10-5 fertilizer, and this is enough for an acre of bearing trees. For younger trees these amounts may be reduced approximately in proportion to the areas actually covered by the fertilizations.

The manure may be applied any time during late winter or spring, but it is probable that the fertilizer will give best results if applied somewhat after the blossoming period. The area of application should be similar to that described above for the mulches, and either the manure or the fertilizer is likely to do as well, if left on the surface, as when worked into the soil by light plowing or harrowing. Checks or typical unfertilized areas should always be left for comparison, with any type of fertilization, until its actual value is known. For further information on this subject the reader is referred to Bulletin 121 of this Station.

Spraying.

The majority of the ills of a bearing orchard can be readily controlled with two materials applied in accordance with the following schedule. These materials are lime-sulphur and lead arsenate. For most scale insects, the lime-sulphur is applied during the dormant season at a density of 1.03 or more, which is obtained by diluting the best of the commercial concentrated solutions at the rate of 1 to a total of 10, or by diluting the 1-2-1 home-made concentrate at about 1 to a total of 8. This material can also be successfully used against scale in summer, if thoroughly applied at the strength indicated below for use on foliage. In the latter case, three sprays are required for complete control, the first preferably being applied immediately after the young begin to emerge and the others following at intervals of about 10 days, or whenever additional young appear.

For the ordinary foliage sprays, a density of about 1.008 (obtained by diluting about 1 to 38 commercial, or 1 to 30 home-made) is best for the lime-sulphur on apples or pears. The lead arsenate is used at the rate of 2 pounds of the paste, or 1 pound of the powder, to 50 gallons of diluted spray and it is usually added to the lime-sulphur solution and applied at the same time[4]. When combined with the latter solution, our experiments have indicated that the tri-plumbic arsenate is safest, though the results are not yet entirely conclusive.

Spraying Plan for Apples or Pears in Foliage.—With the combined spray just described, the proper times of application and the chief enemies controlled by them are as follows. When the enemies named are unlikely to be present, the corresponding spray or its insecticidal or fungicidal part may be omitted.

> (1) **Spray when the blossoms are just showing pink or slightly before.** For apple or pear scab, canker worm and bud moth. Especially needed where scab is bad or weather is damp and cool. Also very essential, with the addition of a tobacco extract or a similar spray as noted below, where aphids or red-bugs are present.
>
> (2) **Second spray may begin when petals are two-thirds off, and it should be completed within 10 days thereafter.** The most important single spray; calyx cups should be filled. For apple worm, scab, curculio and later species of red-bug as noted below.
>
> (3) **Third spray, about two weeks after No. 2.** For codling moth or apple worm, curculio, sooty blotch fungus, and scab. Also useful against the apple maggot, when present.
>
> (4, 5 & 6) In orchards subject to attack by bitter rot or apple blotch, make three additional sprays—preferably with bordeaux (3-3-50)—at intervals of about 3 weeks, beginning 8 or 9 weeks after petal fall.
>
> (7) For second brood of codling moth, late scab infections, or caterpillars of late summer; **use lime-sulphur or bordeaux and lead arsenate as above, about August 1st.** When the second and third applications have been thoroughly made, this one is usually unnecessary, though much depends on the locality and season.

In addition to the more common troubles mentioned above it may be necessary to combat one or more of the following enemies which are becoming very important in some localities. These enemies are the apple aphids or plant lice, the red-bugs, and the apple maggot. The latter pests are especially bad, because they ruin practically all of the fruit infested by them, and in the case of the one last named, there is often little or no indication of their attack on the surface of the fruit.

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[4] See Pa. Bulletin 115 for detailed methods of preparing, diluting and using lime-sulphur; and also Pa. Bulletin 110 for general spraying directions.

Control of the Aphids and Red Bugs.—There are five species of aphids and two of red-bugs that attack the apple. One of these is the woolly-aphis, one effect of which has been shown in Figure 1. When this aphis becomes serious on the roots of trees already planted, the only method of control that has proved really effective is partially to expose the principally infested roots by drawing the soil away for a distance of 2 to 4 feet from the trunk, and to saturate this area with kerosene emulsion at a strength of about ten per cent. From two to seven gallons of emulsion will be required properly to saturate such an area, and the soil should be replaced immediately after the application. As indicated by work in Georgia, where this pest is often very severe, the safest and best time for these applications is apparently during the season of active growth, and not later than the middle of July.

The aerial forms of the woolly-aphis and all the other apple infesting species can be controlled probably best with tobacco extracts, though kerosene emulsions diluted to about 7% of kerosene are often satisfactory. The tobacco extracts should be diluted to about .05 of one per cent. of nicotine sulphate or its equivalent, and they can be added directly to the combined spray used in the plan above without any appreciable reduction in efficiency. These same materials and strengths are the best for controlling the red bugs.

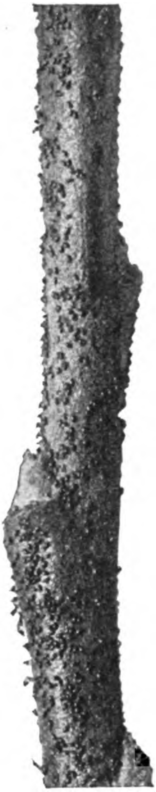

Fig. 8.—Eggs of the Common Apple Aphis. Some of them hatching on the left edge.

The most vulnerable time for the aphids is just as they are hatching or slightly later. The eggs of most species,—shown in Figure 8,—begin hatching about as the buds start swelling or slightly before. The young aphids move at once to the tips of the buds and begin crowding down among the green unfolding leaves, as shown in Figure 9,—a habit which enables them to reach protected situations very quickly. This is the very best time for their control, though much can often be done at the time of the first spray indicated in the plan above.

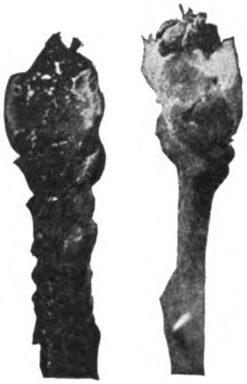

Fig. 9.—Young Aphids Attacking Tips of Apple Buds. The best time for spraying. Taken March 29, 1913, at the College. (Slightly enlarged).

The apple red-bugs are less familiar to most orchardists, although their work, which is shown in Figure 10, is unfortunately not uncommon. The insects themselves become about a quarter of an inch long in the adult stage, and they range from 1.2 to 4.3 millimeters long in the various nymphal stages. One species is known as the red-bug and the other as the false red-bug, though the latter averages the redder of the two.

The nymphs of both species are a brilliant tomato-red at first, with a few dusky markings. The latter becomes more prominent with increasing maturity, especially about the thorax and head in the case of the red-bug. This insect in its adult stage may become nearly black over the fore part of its body, while its dorsal surface is covered with white scale-like hairs. The false red-bug lacks these hairs and its beak is light colored or translucent, with a dusky tip.

The eggs of both species are laid in twigs, preferably in two-year-old wood, late in June or early in July. Those of the red-bug are inserted in slits made at the bases of fruit spurs, while those of the other species are inserted in pairs in the lenticels. The former begin hatching soon after the fruit buds open and are through when the blossoms open. The latter hatch about a week later.

The young nymphs are rather shy and very active. The first indication of their presence is likely to be the clusters of minute reddish dots on the young leaves, caused by the punctures of their needlelike beaks. Their presence may be determined earlier by placing branches of bearing wood in water any time after March first to force out the buds. If present the brilliant red nymphs should appear soon after the leaves. As soon as the fruit is set they begin feeding on it. The fruit most severely punctured usually drops, that remaining on the tree may mature, but it becomes dwarfed, knotty and practically worthless. The infested fruit illustrated in the figure showed an average reduction of more than 61 per cent. in size.

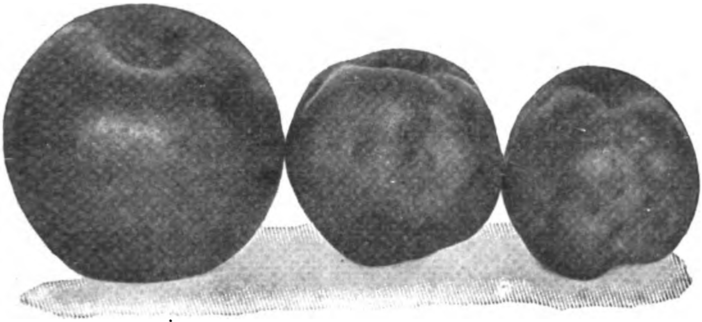

Figure 10.—Fruits on the Right Injured by Apple Red-Bugs. The fruit on the left is a normal Grimes and came from the same tree.

To control these insects, two thorough applications are required. The first should be made **during the interval between the opening of the buds and petals,** for the true red-bug; and the **second** should come **immediately after the petals fall,** for the false red-bug and the stragglers of the earlier species. Fortunately these times correspond with the first two sprays already indicated in the general plan, and hence all that is needed is to add tobacco extract of the strength stated above[5].

Control of the Apple Maggot.—This is also called the "railroad worm" on account of the irregular tunnels or discolored streaks that it makes through the flesh of the apple, the tunnels frequently becoming so numerous as to cause the latter to break down entirely. It is one of the very worst apple pests wherever it occurs, and it has already been noted by the writer at various points in the northeastern portion of the state and extending south and westward as far as Mifflin and Center Counties. The adult of this insect is a fly, slightly smaller than the house-fly, of a blackish color, with yellowish head and legs, and with three or four narrow white bands across the abdomen. Its wings also are marked by four irregular black bands, which distinguish it from similar associated flies.

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[5] For further information on the habits and control of aphids and red-bugs see the writer's article in the annual report of the Station for 1912-1913; and also Bulletin 291 of the Cornell Station.

The eggs are laid within the apple so that the larva or maggot is wholly beyond the reach of any spray, and none of the common methods of gathering and destroying the infested fruit has proved especially effective. Fortunately, however, there is an interval of about two week's between the emergence of the adult and the beginning of egg-laying, and it has recently been found that the adult can be readily poisoned during this period with a sweetened arsenical spray. A spray containing about three gallons of molasses or other cheap syrup, and three pounds of lead arsenate in a total of 50 gallons of spray material has proved quite effective. The adults emerge along in June and there is also a partial second brood in September. Their presence in any infested orchard can be easily determined with the aid of the description above, and one or two applications, at intervals of about 10 days, for each brood immediately after it is observed, should give complete relief from this pest. These sprays are applied on the foliage, preferably of the lower limbs only.

Thinning

Whenever the crop on a tree is too large for normal maturity thinning should always be given. Under such conditions it increases the size of the fruits; avoids breakage; reduces drain on both tree and soil by avoiding unnecessary seed production; and probably increases quality by affording opportunity for normal development. It also doubtless tends to increase the crop of succeeding years, though this has not yet been actually proved experimentally. When needed, thinning should be done as soon as possible after the June drop is largely over. In some localities, later thinnings are also made as the demand arises, with special attention given to the removal of defective fruits, so that the crop at picking time may be practically all first grade.

Picking and Proper Handling of Fruit for Storage

The proper time for picking apples is very important. Too early picking sacrifices color, quality,—both for eating and keeping, —and also fruit spurs; while picking too late results in loss of keeping qualities and often in loss from winds. The best time for picking most apples, therefore, is when they are "hard ripe," i. e., when they have developed their full size and redness, but have not yet begun to soften nor to show the yellow colors, except perhaps in occasional specimens. Apples that develop no red color are picked when they have reached full size, or when occasional specimens have begun to soften or to part readily from the twig. Summer and early autumn varieties, intended for immediate use, are best ripened on the trees, otherwise they should be picked as above. In many cases, two or more pickings are found desirable and profitable to permit undeveloped fruits to mature.

In addition to picking at the right time, the best keeping qualities are secured by avoiding bruises and broken skins and by immediate cooling of fruit. Leaving the apples in piles with the sun beating on them is exceedingly damaging to keeping quality. The minute bruises which soon appear in storage are best avoided by picking in round-bottomed, cloth-lined, swing-handled baskets. In storage, temperatures of about 30° to 35° F. are satisfactory. A good storage house, or rented space in one, relieves one of the necessity of selling at once and thus often secures distinctly better prices, even at picking time. The best kind for the commercial orchardist to own is probably one using the gravity brine system.

The Packing of Apples

In general, the essentials of a good pack are: clean, odorless packages; fruit strictly true to grade throughout; reasonable uniformity in size and color; and sufficient compression to avoid looseness in transit. The labeling and varietal name should be correct, and the name and address of the grower or the person in whose interest the packing is done should be given[6]. It is usually good business to pack in this way, wholly aside from any other consideration, as such fruit regularly commands the highest prices on any market in which it becomes known, especially when the grower also stands back of it with a substantial guarantee.

The particular style of package varies with the conditions to be met. Early apples are usually best marketed in peach backets, unless the distances are too great. For the later varieties, barrels or boxes are preferable. The relative value of the latter packages depends largely upon the amount of fruit to be marketed, and upon its uniformity, perfection and quality. For the general wholesale marketing of the East, the barrel is undoubtedly best, and the greatest total gains are doubtless obtainable by thoroughly improving and standardizing the methods of packing it[6]. For strictly high grade and high quality fruit, however, the best returns are usually secured by proper packing in boxes, or similar packages, and by developing a trade directly with the consumer, or at least a trade that involves no more than one middleman. It is also highly essential, especially in full-crop years, to keep the poor fruit off the general markets, if their complete demoralization is to be avoided. Such fruit should always be disposed of locally, if possible, either by not growing it, or by way of canneries, evaporators, cider mills, or other special markets. If sent to the general markets, it should be shipped in bulk.

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[6] The recent national legislation on this matter may be secured by writing local Congressmen for copies of the Sulzer apple-packing law.

With the box-pack, the most efficient form depends largely upon the way in which it is handled. For car lots, with careful packing and proper handling throughout, the present apple-box with its elastic, bulging top and bottom is satisfactory,—at any rate it has set the fashion. It is made preferably of planed white spruce, with solid ends and sides,—¾ and ⅜ of an inch in thickness, respectively. The tops and bottoms are usually made of quarter-inch material, and the cleats of the same thickness. The size of these boxes unfortunately is not yet uniform. The legal box in Canada and the "special" of the far West are 10x11x20 inches, while the "standard" box of the latter section is 10½x11½x18,—all inside measurements[7].

For the smaller shipments and customary handling, however, this package is usually quite severe on the fruit, even when the best diagonal packs are used. This difficulty has been largely overcome by some growers by eliminating the bulge and using the regular ⅜ material for the tops and bottoms as well as the sides. This arrangement requires very careful packing so as to just fill the definite space at hand, and in strict justice the dimensions of such a box should be increased somewhat to make up for the loss of the bulge.

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[6] The recent national legislation on this matter may be secured by writing local Congressmen for copies of the Sulzer apple-packing law.

[7] For details of packing see Cornell Bulletin 298; the files of *Better Fruit;* Oregon Bulletin 94; Bulletin 19, Dairy and Cold Storage Commission Series, Ottawa, Canada; and Paddock & Whipple, "*Fruit-Growing in Arid Regions.*"

All these difficulties are cleverly met in a box, devised by a Canadian. In this box the bulge is protected by widening the sides by 1½ inches, shortening the tops and bottoms so that they will just fit inside the ends, and lengthening the ends so that the cleats can be nailed on the inside of them after pressing the tops down snugly against the fruit, regardless of its exact height. This package should be especially useful in the smaller shipments, or in any that are likely to involve much rough handling, and the only important objection to it apparently lies in the fact that when opened it will appear less full than the ordinary box. It should be tried in a small way, therefore, before adopting it for the entire crop[8].

Varieties

The ideal variety should be of good size, attractive color, and high quality; have a sound, productive, early-bearing tree; and be adapted to the particular location involved. To meet successfully future competition, such varieties, preferably red, are required. Since all these qualities are found in very few varieties it is usually necessary to sacrifice some of them in many of the varieties selected, but they should be obtained so far as possible.

In the list below, we have named the varieties that are likely to be most satisfactory in this state. The state is divided into two general divisions, and the varieties considered best for each are listed approximately in order of ripening, *with the exception* that those separated by colons (:) are of practically the same season. The varieties marked with two asterisks (**) are considered to be fully commercial; those with one asterisk (*) limited commercial; and those marked with a dagger (†) are good as fillers. The others may be limited commercial in some localities or are good for home use.

The soil preferences of certain varieties, so far as known, are indicated by letters after the varietal name; thus H (heavy) stands for clay loam, M (medium) for intermediate soils or loams and L (light) indicates light soils or sandy loams. These preferences, however, may be largely overruled by changes in latitude, and in general as a variety is brought southward the heaviness of the soil should be increased, and vice versa. Also, so far as possible, the local behavior and soil preference of any variety should always be carefully noted before assuming any large risk in its planting.

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[8] The exact dimensions of seasoned stock used in making this box are as follows: *Ends*, 11x12x⅞ inches; *Sides*, 11½x21¾x⅝; *tops and bottoms* 10⅞x19⅞x¼; *cleats*, ⅝x10½x½ inches. The 12-inch end dimension is cut "with the grain" and placed vertically in the box. Further details on its construction and merits may be found in *Better Fruit* for September, 1912, page 27.

The number of varieties that one should plant depends chiefly on the distance and character of the market. For home use or local markets or for a trade directly with the consumer, more varieties may be used. For most situations, however, 8 or 10 varieties, ranging through the season, are ample even for large plantings.

A Varieties for Southern Pennsylvania, and Lower Altitudes in Central Pennsylvania.

Summer Varieties

Yellow Transparent**†.—Early July. Hardy, early bearer and productive; scab resistant; erect and vigorous grower, though not large; quality medium; sour; very tender in texture when fully ripe; and the tree is often subject to blight. A Russian variety.

Early Harvest.—Subject to scab, and less prolific than Transparent; usually irregular in size, but good for home use because of high quality.

Earlyripe*.—Vigorous grower and blight resistant; ripens very quickly and liable to drop; early and satisfactory in bearing; excellent cooker and one of the best shippers and general purpose apples of its season. Size good but color yellowish-green, and hence needs to be known before fully successful on a market. Often difficult to get true to name. Has been confused with Lowell, a later and poorer variety, by some nurseries.

Primate.—One of the best of its season for the home orchard owing to its high quality, good size, long period of ripening, and fair productiveness. Tree rather susceptible to canker and fruit too tender for ordinary commercial use.

Benoni*.—Excellent for dessert; good tree; bears fairly young and well. Fruit largely red, often too small for general market unless well thinned. Aug. and Sept.

Starr*.—Early and prolific; fruit usually large; fair for dessert and excellent for cooking; good shipper; considered fully commercial in central New Jersey. Said to do well on light soils.

Oldenburg (*Duchess*)**†.—More widely reported as valuable commercially than any other variety of its season. Very early bearer and regularly productive, but usually short-lived; fruit of good size and appearance; for cooking, too sour for dessert.

Williams (*Red*)*.—Regarded in Delaware as one of the best summer apples. Good for both dessert and cooking; firm in texture and ships well. Tree requires careful pruning when young. Not sufficiently tried in southern Pennsylvania as yet but its behavior elsewhere warrants extended trial; probably fully commercial in parts of this state under right conditions and care.

Early Autumn Varieties

Summer Rambo**.—A leader in southern and southeastern counties. Tree vigorous and hardy, early and annual bearer. Ripens over long season. Fruit large, attractive, and of high quality; good keeper for its season; rather tender in texture for rough handling and needs several pickings to avoid loss by dropping.

Maiden Blush.**—M to H. Good for home or market. Tree hardy and vigorous, of spreading habit. On most soils it eventually needs 40x40 feet space. Often needs thinning to secure uniformity, needs careful handling to avoid bruises, and usually must be thoroughly sprayed for scab.

Jefferis.—Excellent for home orchard; quality delicious; season long,—Sept. to Dec. Size medium; blushed and splashed with red. Tree moderately vigorous, bears fairly young, good yielder.

Wealthy*†—Erect grower, very hardy and probably better adapted to colder sections. Bears young, usually biennially and heavily; fruit of good size and of excellent appearance on young trees, but becomes undersized on old ones unless strongly thinned or renewal-pruned. On heavy soils the fruit may become too soft for ordinary shipping even before coloring. Good for dessert or cooking.

Late Autumn and Winter Varieties

Smokehouse.**—M. Vigorous grower and usually productive; develops a tangled and dense head, with drooping branches, hence needs rather high heading, careful prunning and spraying, and plenty of space in the orchard. Fruit in its prime is of high quality and usually of good size; a general favorite wherever known, notwithstanding rather dull color.

McIntosh*†.—See discussion in Section B.

York Stripe*.—Originated in Adams County before its separation from York. A valuable variety, quite similar to Rome Beauty in appearance, size and quality, but with a better tree. Apparently worthy of more general use.

Grimes.**—M to H. Fruit unexcelled in quality and of good appearance if carefully handled. The tree, however, has a weak root-system, is very susceptible to collar blight or other trunk diseases, and hence is often short-lived, a difficulty which may be overcome by topworking on a more vigorous stock. With this defect remedied and with proper soil and good care it is fully commercial. In topworking it is probably advisable to select scions from best individuals.

Jonathan*†.—L. Fully commercial under proper soil conditions and care. It has unexcelled appearance, high quality, early and abundant bearing and brings top prices in its season. Best on a light, mellow, gravelly loam or upon a sandy loam with retentive subsoil, and good air drainage. Chief faults are fruit spot, a physiological disease which is especially bad some seasons, and a tendency to run small, especially on old trees, unless properly thinned.

Rome Beauty†.**—L to M. Has done very well in adjoining states and is very promising commercially in many parts of Pennsylvania, especially in the southwestern sections. The tree bears unusually early, and the fruit is of fine appearance and exceptionally free from fruit spot or other blemishes, as a rule. Quality good, but not high. An apparent off-shoot of this variety, known as the **Ensee**, is higher in quality and apparently equal to the Rome in other respects.

Stayman Winesap.**—M. Probably now being planted more than any other varieties in southeastern Pennsylvania and adjoining states. Much larger than the old Winesap, though not so well colored. Tree very vigorous and rather early bearer. Its size, high quality and long keeping bring for it high prices wherever known.

York Imperial.**—M to H. Originated in York County. Moderately early bearer, and very productive; decidedly biennial, a habit that may be lessened by heavy thinning and fertilization on the full year. Fruit attains fine appearance and a good quality if permitted to mature properly on the trees. Excellent for cooking, in which most apples are used. Resistant to scale but rather susceptible to blight. At present the tendency in planting seems to be toward higher-quality varieties, though this is quite profitable if properly handled.

Stuart (*Golden*).—Similar to Grimes in appearance and quality, but much later keeper and better tree. Of Ohio origin, apparently well suited to this section. Difficult to obtain from nurseries, not the same as Fulton.

Gano.—This variety together with Ben Davis, of which it is a strain, is an early bearer, and produces fruit of fine appearance and excellent keeping and shipping qualities. Quality and reputation on market are low, however, and it is very susceptible to injury by scale, curculio and codling moth. For these reasons, its commercial planting, as well as that of Ben Davis and its allies, is not advisable.

Paragon, and Black Twig or Arkansas*.**—These two varieties are very similar and so hopelessly confused in most nurseries and elsewhere that they are considered together here. They are very late keepers, of the winesap type but larger, firmer and much more vigorous growers. Excellent appearance, and much above the average in quality when well grown. Sometimes rather tardy in bearing, and only adapted to the southern part of the state. The Paragon is preferable, if it can be obtained.

(See also varieties in Section C; and some of those in Section B may be used in the southern portion if placed on relatively heavy soils).

B. Varieties for Northern Pennsylvania and the Higher Altitudes In Central Pennsylvania.

Summer Varieties

Yellow Transparent†, Oldenburg** (*Duchess*)****†**, and **Williams** (*Red*)*****.—Varieties discussed above.

Red Astrachan*.—A Russian Variety, widely grown and recommended. Fairly productive, but often tardy in bearing. Fruit usually irregular in size; uneven ripener, and often overstocked on the market, where it quickly loses its prime.

Early Autumn Varieties

Chenango.—A beautiful, high-quality apple, well recommended for home and local market but too tender for ordinary distant shipping. Tree usually early and regular in bearing, and relatively free from disease, but is undersized and a poor grower.

Mother.—An excellent dessert apple of the Spitzenburg type, often known locally as the spice apple. Especially good for the home orchard and frequently useful in limited commercial planting.

Alexander.—A large, coarse, but well-colored apple of low quality and Russian origin, for which there seems to be some demand on certain markets. Tree is hardy and moderately productive. Better than it's relatives, the Wolf River and Bismarck, and possibly of limited commercial value near certain markets.

Wealthy†: Maiden Blush***—(See discussion in list A). The Wealthy should be one of the commercial leaders in this section.

Gravenstein*.—Unexcelled for cooking by any variety of its season and also good for dessert. Usually bears fairly early; productiveness variable but reported very good in northeastern part of the State. Tree large and vigorous. Fruit is large, but is apt to be irregular and is subject to loss by dropping.

Late Autumn and Winter Varieties

Twenty Ounce.—Often in good demand on account of large size and good cooking qualities. Tree medium size, poor grower, with a dense, erect top unless carefully pruned. Often subject to sunscald, blight and canker and also to spray injury. Sports of this variety, known as Collamer and Hitchings, are better colored.

Fall Pippin*.—One of the most desirable of its season for the home orchard and often of much value commercially, if properly handled. Tree very vigorous and long-lived, of spreading habit. Fruit large and attractive; ripens over a long season; rather susceptible to scab both in fruit and foliage.

McIntosh**†.—H. A very handsome and high quality apple of the Fameuse or Snow type, but larger, redder and more widely adapted. Often subject to scab unless properly sprayed. Bears young and is one of the very best commercial varieties of its season, especially in the higher altitudes, though it does well over most of the present sections when properly cared for. Sells very well in most markets.

Hubbardston*†.—L to M. Apt to require thinning to keep up size and normal development. Extremely susceptible to borers, especially on light soils; hence requires special protection either by means of proper coverings or possibly by topworking. Fruit large, often subject to dropping in absence of sufficient moisture, and shrivels in storage. Good in quality and appearance.

Smokehouse*.—(Discussed above). This variety is less valuable toward the northern limits of this section, but has done well as far north as Pittston.

Tompkins King.—M. Large, high quality, good appearance, and often brings highest prices on New York markets; but tree is short-lived unless topworked on a more hardy stock, and is only fairly productive. May be useful as a semi-permanent.

Northern Spy**.—Widely grown in northern Pennsylvania, where it succeeds well, especially in the higher altitudes. Chief faults are tardiness in bearing and susceptibility to a soft rot of the fruit unless properly handled at picking time. Its vigor of growth, high quality and regular and abundant bearing with age are likely to keep it a favorite for some time, however, though the faults named are undoubtedly a considerable handicap to new plantings.

R. I. Greening*.—M to H. Excellent both for cooking and dessert. Varying reports of its value in northern Pennsylvania are received, the difference being probably due to local conditions and handling. It should be valuable on the heavier soils with proper care.

Wagener.—One of the earliest to come into bearing and of rather dwarfish form, hence considerably used as a filler especially in connection with Spy. Properly grown fruit is of high quality but it is usually quite variable in size, and requires thinning of the smaller apples, which are of little value.

Esopus (*Spitzenburg*).—Of excellent quality and good reputation on the general market but of doubtful value for anything but the home orchard in Pennsylvania.

Baldwin**.—M. to L. A standard apple on the market and prolific with age, but becoming so badly affected by fruit pitting, etc., in some places, as to make one cautious in its further planting. Under proper conditions it is well adapted to the northern part of the state. Tree excellent but often rather tardy in bearing, unless carefully handled.

Stayman Winesap*†.—L to M. Probably not so well adapted to the northern section of the state as some other varieties, and if planted there it should be confined to the lighter soils and lower altitudes. See its discussion in the preceding section.

Rome Beauty**†.—Notwithstanding its more southern origin, the behavior of this variety in Erie County and in parts of New York indicates it to be the most likely substitute for Baldwin where the latter is too much affected by the fruit pit trouble. See discussion in Section A.

Yellow Bellflower.—M to L. A large, yellow variety, excellent both for dessert and cooking, in season about from December to April. Needs good spraying, careful handling to avoid bruises, and prompt transfer to storage to secure best keeping. Tree healthy, vigorous and productive with the right soils and care.

Stark*.—Fruit large, smooth, uniform, relatively free from disease, and fairly well colored if properly grown and matured before picking. Excellent cooker, medium for dessert, and often keeps until June in ordinary storage. Tree very vigorous, hardy; spreading habit, reliable and heavy yielder. A good substitute for Baldwin, where latter is much affected by disease.

C. Varieties Worthy of Trial.

Livland Raspberry (*Lowland Raspberry*).—A Russian variety now attracting some attention. Fruit medium to large, clear waxen-white, striped and shaded with light crimson. Flesh white, often tinged with pink near the skin, pleasant mild subacid. Ripens about with Early Harvest. Tree is reported to be very hardy, healthy, vigorous and long-lived,.late in blooming and blight resistant.

Wilson June (*Wilson Red June*).—Fruit somewhat of the Red June type, though considerably larger. Tree thrifty and apparently productive. Originated in Washington County, Arkansas, and now being grown over a wide range of territory.

Magnate (*Magnet*).—Similar origin and type as Stayman, but better colored and earlier. Probably well adapted to southern part of the state. Season about with Jonathan, and on medium to heavy soils it is doubtless preferable. Fruit medium to large; prevailingly crimson red, indistinctly striped with dark purple, and usually covered with a whitish bloom. Tree upright, open grower, requiring little pruning.

Opalescent.—Found as a seedling at Xenia, Ohio, in 1899. A valuable new variety that should do well in this state, especially in the northern half, since it is doing finely as far north as Maine. Fruit especially good in appearance, being large well-formed, and nearly or wholly covered with red. Quality also excellent. Trees thus far have been hardy, vigorous and productive. One of the very best varieties at the Geneva Station, in New York.

Banana (*Winter Banana*).—Resembles Maiden Blush in general appearance but is later,—season about with R. I. Greening. Of Indiana origin, quite successful in the far west. Fruit is large, somewhat irregular in size; characteristically aromatic; clear, pale yellow, with a pinkish-red blush and often with suture lines; very good for dessert. Tree medium-sized, with flat, open habit of growth; rather subject to blight.

Delicious*.—Originated in Iowa about 1881, from the stock of a Yellow Bellflower. Fruit medium to large, rather dull red with darker stripes over a greenish-yellow ground; mild, subacid, aromatic and very good. Flesh rather tender, with some tendency to soften about the core, and needs good spraying for scab. Tree large, vigorous, hardy and productive, quite promising in many parts of this and adjoining states, but needs plenty of moisture and a fairly long growing season to keep up size.

King David.—Fruit of the old winesap type, especially in size and color, though it averages darker red. Flavor rather sharply acid, and not equal to the old winesap in quality. Tree very vigorous, but fruit is too small for general commercial use.

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9. See U. S. Department of Agriculture Yearbook, 1906, pp. 255-257.
10. See U. S. Department of Agriculture Yearbook, 1907, pp. 305-307.

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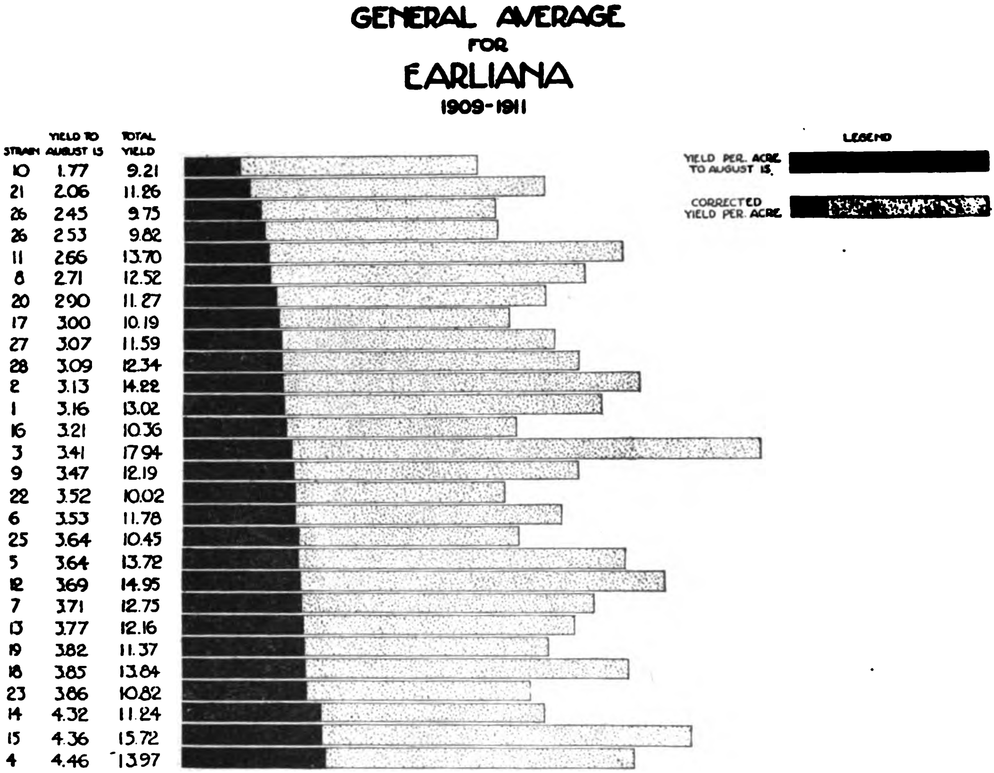
The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 129



STRAIN TESTS OF TOMATOES

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
MARCH, 1914.

AGRICULTURAL EXPERIMENT STATION
THE PENNSYLVANIA STATE COLLEGE

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The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 129

STRAIN TESTS OF TOMATOES

By C. E. MYERS

Historical Note

In the spring of 1908 an experiment was instituted for the purpose of determining the relative values of strains of cabbage and tomato seed when secured from different sources. The results of the experiments with cabbage have already been published*. It is the purpose of the present bulletin to give a brief summary of the work with tomatoes, the complete record of which appears in the Annual Report for 1912-1913.

A preliminary test was conducted in 1908 with the varieties Earliana and Chalk Jewel of twelve strains** each, and with Matchless of eleven strains. This test showed the desirability of enlarging the experiment, and accordingly the following year, seed was secured in ounce packages of twenty-eight strains of Earliana, twenty-six strains of Chalk Jewel, twenty-five strains of Matchless, twenty-five strains of Beauty, twenty-four strains of Globe and twenty-six strains of Stone. These strains as well as those secured in 1908 have been tested during the years 1909, 1910 and 1911.

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*See Bulletins 96 and 119 of the Pennsylvania Agricultural Experiment Station and also Annual Report 1911-1912.

**In this bulletin each lot of seed is designated as a strain.

Soil and Fertilization

These experiments have been conducted on the Experiment Station farm, the soil of which is Hagerstown clay loam and is naturally fertile. In addition to the natural fertility of the soil, barnyard manure and home-mixed fertilizers have been used in sufficient amounts to produce a good growth, but in no case has the fertilization been excessive. The plantings were made in locations where the soil was uniform in texture and contour and for the years 1910 and 1911 checks were used and corrections made for apparent variations in soil fertility. Thus, any differences in the general character of the fruit or of the yield may be attributed to inherent differences in the seed.

Factors Considered in the Experiment

In the purchase of seed, one of the first questions for consideration is, "will it grow." The official standard of vitality of tomato seed is 98%. The germination of the seed secured for these experiments ranged from 37 to 100 per cent. The vitality represented by the first extreme is far too low, and no seedsman should put seed of this grade on the market; however, in most instances the vitality was quite satisfactory, and by making a germination test sufficiently early, the sowing could be made at a rate which would insure a satisfactory stand of plants.

One important factor which was noted in the experiment was that in some varieties the strains were not true to name or were mixed with other varieties. For example, of the twenty-six lots bought for strains of Chalk Jewel, two were Matchless; two were a mixture of Matchless and Chalk Jewel; one was mixed with Beauty; and one was a mixture of Chalk Jewel, Matchless and Beauty. Furthermore, these characteristics of the particular strains were noted for each of the respective years of the test. Aside from the factors previously noted, the size of fruit, percentage of marketable fruit, earliness and productiveness are factors of primary consideration. They are of especial interest because of the fact that they may be definitely measured, and the variation in the respective strains shown by figures. It is these values as shown in the following tables with which we are particularly concerned.

The following table shows the record of the test of Earliana for the years 1908-1911:

Table I.—General Average for Earliana, 1908-1911.

Record No.	SOURCE	Av. wt. of marketable fruit	Per cent. of fruit marketable[3]	Yield to Aug. 15	Corrected yield per acre[2]
1a	W. Atlee Burpee, Philadelphia, Pa........	.23 Lbs.	78	2.16 T	14.23 T
2a	H. A. Dreer, Philadelphia, Pa............	.24	79	2.15	14.46
3a	Wm. Ewing, Montreal, Canada...........	.25	76	2.09	11.47
4a	D. M. Ferry, Detroit, Mich..............	.22	76	1.68	15.82
5a	Peter Henderson, New York, N. Y.......	.22	76	2.15	14.91
6a	H. F. Michell, Philadelphia, Pa...........	.23	79	2.76	20.17
7a	The Livingston Seed Co., Columbus, Ohio.	.24	79	2.30	18.62
8a	W. P. Stokes, Philadelphia, Pa............	.23	74	2.36	16.29
9a	J. M. Thorburn & Co., New York, N. Y...	.24	78	2.00	15.03
10a	Jas. Vick's Sons, Rochester, N. Y..........	.23	77	2.00	12.64
11a	Webber & Don, New York, N. Y.........	.24	80	2.60	13.33
12a	George Keith, Toronto, Canada..........	.23[3]	78[2]	2.10	14.93[1]

[1] Average for one year.

[2] Average for two years.

[3] Average for three years.

[2] By "corrected yield" is meant the total yield after having been corrected for apparent variations in the fertility of the soil. In the opinion of the writer, it most nearly expresses the yielding property of a strain. For method of determination, see Annual Report of 1911-12.

A study of the above table shows that the average size of fruit and the per cent. of marketable fruit were fairly constant, while the yield to August 15 ranged from 1.68 to 2.76 tons, or more than a ton per acre, and the corrected yield ranged from 11.47 to 20.17 tons, a difference of 8.70 tons per acre in favor of the better yield. There was a similar and consistent variation in the general character of the fruit.

The next table shows the record of the test of Earliana, the seed of which was secured in 1909, the figures given being the averages for the years 1909-1911.

Table II.—General Average for Earliana, 1909-1911.

Record No.	SOURCE	Av. wt. of marketable fruit	Per cent. of fruit marketable	Yield to Aug. 15	Corrected yield per acre*
1	J. Bolgiano & Son, Baltimore, Md.	.24 Lbs.	85	3.16 T	13.02 T
2	Francis Brill, Hempstead, N. Y.	.22	82	3.13	14.22
3	H. W. Buckbee, Rockford, Ill.	.24	80	3.41	17.94
4	H. A. Dreer, Philadelphia, Pa.	.24	85	4.46	13.97
5	D. M. Ferry & Co., Detroit, Mich.	.25	82	3.64	13.72
6	Griffith & Turner, Baltimore, Md.	.24	80	3.53	11.78
7	Peter Henderson, New York, N. Y.	.22	82	3.71	12.75
8	Holmes Seed Co., Harrisburg, Pa.	.24	84	2.71	12.52
9	Leonard Seed Co., Chicago, Ill.	.23	82	3.47	12.19
10	Livingston Seed Co., Columbus, Ohio	.22	77	1.77	9.21
11	W. H. Maule, Philadelphia, Pa.	.25	86	2.66	13.70
12	H. F. Michell, Philadelphia, Pa.	.29	81	3.69	14.95
13	State College	.25	87	3.77	12.16
14	W. P. Stokes, Philadelphia, Pa.	.25	82	4.32	11.24
*15	Texas Seed & Floral Co., Dallas, Texas	.25	81	4.36	15.72
16	J. M. Thorburn, New York, N. Y.	.24	81	3.21	10.36
17	Webber & Don, New York, N. Y.	.23	83	3.00	10.19
18	T. W. Wood & Son, Richmond, Va.	.23	78	3.85	13.84
19	Moore & Simon, Philadelphia, Pa.	.23	81	3.82	11.37
20	Jas. Vick's Sons, Rochester, N. Y.	.22	78	2.90	11.27
21	W. C. Beckert, Pittsburgh, Pa.	.23	83	2.06	11.26
22	Wm. Ewing, Montreal, Canada	.24	79	3.52	10.02
23	Jos. Harris, Coldwater, N. Y.	.22	80	3.86	10.82
24	W. W. Rawson, Boston, Mass.	.22	81	2.53	9.82
25	W. Atlee Burpee, Philadelphia, Pa.	.23	80	3.64	10.45
26	W. F. Allen, Salisbury, Md.	.22	78	2.45	9.75
27	C. C. Hulsart, Mattawan, N. J.	.23	82	3.07	11.59
28	H. P. Langdon, Constable, N. Y.	.23	80	3.09	12.34

* Two year average.

A study of the foregoing table shows that the variation in the size of fruit was quite pronounced in that it varied from .22 to .29 pounds while the percentage of marketable fruit was fairly uniform. The variation in earliness is of considerable interest. It will be seen that the average yield to August 15 ranged from 1.77 to 4.46 tons, a difference of 2.69 tons per acre in favor of the superior strain. The early maturing strain also ranked fifth in corrected yield and the field notes show that it was otherwise desirable. It will also be observed that the productiveness of the various strains ranged from 9.21 to 17.94 tons, although in this case the highest yielding strain was not very desirable in character of fruit.

The next table shows the average of the test of Chalk Jewel, the seed of which was secured in 1908.

Table III.—General Average for Chalk Jewel, 1908-1911.

Record No.	SOURCE	Av. wt. of marketable fruit	Per cent. of fruit marketable	Yield to Aug. 15	Corrected yield per acre
1a	W. Atlee Burpee, Philadelphia, Pa........	.22 Lbs.	79	1.56 T	11.38 T
2a	H. A. Dreer, Philadelphia, Pa............	.26	83	2.00	12.00
3a	Wm. Ewing, Montreal, Canada...........	.23	81	2.78	13.86
4a	D. M. Ferry, Detroit, Mich..............	.23	82	2.19	18.21
5a	Peter Henderson, New York, N. Y.......	.20	77	1.54	17.28
6a	H. F. Michell, Philadelphia, Pa..........	.25	82	1.95	17.83
7a	The Livingston Seed Co., Columbus, Ohio.	.23	76	1.37	14.84
8a	W. P. Stokes, Philadelphia, Pa............	.23	80	.65	17.45
9a	J. M. Thorburn & Co., New York, N. Y...	.22	77	1.17	15.60
10a	Jas. Vick's Sons, Rochester, N. Y..........	.22	77	.97	15.37
11a	Webber & Don, New York, N. Y.........	.25	82	1.37	15.56
12a	George Keith, Toronto, Canada..........	.22	78	2.30*	16.57*

* Average of two years.

From the preceding table, it will be seen that the size of the fruit varied from .20 to .26 pounds while the percentage of marketable fruit was fairly uniform; however, it will be seen that the variation in yield to August 15 ranged from .65 to 2.78 tons per acre, and there was a corresponding difference in the general character of the fruit. The variation in corrected yield ranged from 11.38 to 18.21 tons, a difference of 6.83 tons per acre in favor of the higher yielding strain. In this instance, there was practically no difference in the general character of the fruit, of the strains representing the extremes, but the fact that there was a difference of nearly six and one-half tons per acre in yield shows the importance of these variations which are frequently overlooked.

The next table gives the average of the test of Chalk Jewel, the seed of which was secured in 1909.

Table IV.—General Average for Chalk Jewel, 1910-1911.

Record No.	SOURCE	Av. wt. of marketable fruit	Per cent. of fruit marketable	Yield to Aug. 15	Corrected yield per acre[2]
1	J. Bolgiano & Son, Baltimore, Md........	.24 Lbs.	78	.98 T	15.21 T
2	Francis Brill, Hempstead, N. Y...........	.23	73	1.93	14.47
3	H. W. Buckbee, Rockford, Ill.............	.20	77	1.20	13.84
4	H. A. Dreer, Philadelphia, Pa.............	.24	73	.98	14.37
5	D. M. Ferry & Co., Detroit, Mich........	.27	77	2.20	14.35
6	Griffith & Turner, Baltimore, Md.........	.22	75	1.18	12.70
7	Peter Henderson, New York, N. Y........	.23	68	1.17	13.42
[1]8	Holmes Seed Co., Harrisburg, Pa..........	.24	67	.37	12.01
9	Leonard Seed Co., Chicago, Ill............	.23	79	1.30	13.86
[3]10	The Livingston Seed Co., Columbus, Ohio.	.26	70	1.40	15.30
11	W. H. Maule, Philadelphia, Pa............	.26	77	1.68	14.85
[4]12	H. F. Michell, Philadelphia, Pa...........	.24	69	1.50	17.69
13	State College	.24	75	1.04	14.89
14	W. P. Stokes, Philadelphia, Pa............	.22	73	1.62	13.93
15	Texas Seed & Floral Co., Dallas, Texas...	.22	74	1.41	15.17
16	J. M. Thorburn, New York, N. Y.........	.22	73	1.52	15.44
17	Webber & Don, New York, N. Y..........	.25	76	1.47	19.07
[1]18	T. W. Wood & Son, Richmond, Va.......	.27	69	.37	20.15
19	Moore & Simon, Philadelphia, Pa.........	.25	78	1.73	21.05
20	Jas. Vick's Sons, Rochester, N. Y..........	.27	76	.95	19.29
[3]21	W. C. Beckert, Pittsburgh, Pa............	.23	76	.92	20.25
22	Wm. Ewing, Montreal, Canada............	.25	73	1.32	19.26
23	Jos. Harris, Coldwater, N. Y...............	.24	79	1.97	18.09
24	W. W. Rawson, Boston, Mass............	.24	74	1.77	18.59
25	W. Atlee Burpee, Philadelphia, Pa........	.24	72	1.55	16.13
26	W. F. Allen, Salisbury, Md................	.22	72	2.03	18.28

[1] These were Matchless.
[2] Average for two years.
[3] Mixed with Matchless.
[4] Mixed with Matchless and Beauty.

A study of this table shows that the size of the fruit varied from .20 to .27 pounds and the per cent. of marketable fruit from 67 to 79. It will also be seen that the yield to August 15 varied from .92 to 2.20 tons per acre, while the corrected yield varied from 12.70 to 21.05 tons, a difference of more than eight tons per acre in favor of the superior strain. The field notes show that the general character of the high yielding strain was quite desirable.

A study of the table also shows that two of the strains were not true to name, while others were considerably mixed.

The next table shows the average of the test of Matchless, the seed of which was secured in 1908.

Table V.—General Average for Matchless, 1908-1911.

Record No.	SOURCE	Av. wt. of marketable fruit	Per cent. of fruit marketable	Aug. 15 Yield to	Corrected yield per acre[2]
1a	W. Atlee Burpee, Philadelphia, Pa........	.26 Lbs.	81	5.56 T	13.59 T
2a	H. A. Dreer, Philadelphia, Pa............	.25	79	6.18	13.58
3a	Wm. Ewing, Montreal, Canada..........	.25	81	6.78	14.18
4a	D. M. Ferry, Detroit, Mich..............	.26	79	5.96	15.11
5a	Peter Henderson, New York, N. Y......	.21	79	7.55	12.13
6a	H. F. Michell, Philadelphia, Pa..........	.25	81	5.67	15.32
7a	The Livingston Seed Co., Columbus, O..	.27	79	7.80	15.22
8a	W. P. Stokes, Philadelphia, Pa..........	.24	81	7.24	17.74
9a	J. M. Thorburn, New York, N. Y........	.25	79	5.78	13.69
10a	Jas. Vick's Sons, Rochester, N. Y........	.24	81	5.96	14.83
[3]11a	Webber & Don, New York, N. Y........	.26	79	5.82	15.67[1]

[1] Record for one year.
[2] Average of two years.
[3] Average of three years.

In the production of this variety, earliness of maturity is not a matter of primary importance; however, we see that the variation in yield to August 15 ranged from 5.56 to 7.80 tons per acre, while the corrected yield ranged from 12.13 to 17.74 tons, a difference of 5.61 tons per acre in favor of the superior strain. The variation in size of fruit was somewhat pronounced and the variation in per cent. of marketable fruit somewhat less; however, it is interesting to note that the high yielding strain produced a large percentage of marketable fruit.

Table VI gives the average of the test of Matchless, the seed of which was secured in 1909.

Table VI.—General Average for Matchless, 1909-1911.

Record No.	SOURCE	Av. wt. of marketable fruit	Per cent. of fruit marketable	Yield to Aug. 15	Corrected yield per acre[3]
1	J. Bolgiano & Son, Baltimore, Md........	.24 Lbs.	76	5.58 T	13.98 T
2	Francis Brill, Hempstead, N. Y...........	.26	76	2.25	12.77
3	H. W. Buckbee, Rockford, Ill.............	.25	76	2.95	12.89
4	H. A. Dreer, Philadelphia, Pa.............	.25	76	3.91	14.07
5	D. M. Ferry & Co., Detroit, Mich........	.28	79	3.47	15.36
6	Griffith & Turner, Baltimore, Md.........	.28	72	3.81	14.24
7	Peter Henderson, New York, N. Y........	.24	76	3.81	14.78
[3]8	The Holmes Seed Co., Harrisburg, Pa.....	.21	82	8.63	17.36
9	Leonard Seed Co., Chicago, Ill............	.28	76	3.29	16.28
10	The Livingston Seed Co., Columbus, Ohio	.28	71	2.71	14.33
11	W. H. Maule, Philadelphia, Pa............	.26	76	3.45	19.85
[3]12	H. F. Michell, Philadelphia, Pa..........	.21	74	6.61	16.25
13	State College	.25	67	4.72	16.78
14	W. P. Stokes, Philadelphia, Pa............	.25	72	3.88	17.68
15	Texas Seed & Floral Co., Dallas, Texas...	.25	71	3.30	17.73
16	J. M. Thorburn, New York, N. Y.........	.25	70	2.78	13.92
17	Webber & Don, New York, N. Y..........	.26	67	2.58	15.20
18	T. W. Wood & Son, Richmond, Va........	.28	73	2.30	12.92
19	Moore & Simon, Philadelphia, Pa.........	.23	68	3.77	11.23
20	Jas. Vick's Sons, Rochester, N. Y..........	.26	71	2.34	12.32
21	W. C. Beckert, Pittsburgh, Pa.............	.23	71	5.50	11.43
22	Wm. Ewing, Montreal, Canada............	.23	74	5.23	11.95
[2]25	W. Atlee Burpee, Philadelphia, Pa........	.30	69	4.30	9.59[1]

[1] Record for one year.
[2] Average of two years.
[3] These are Chalk Jewel.

This table shows that, disregarding the two strains which were not true to name, the size of fruit varied from .23 to .30 pounds. The yield to August 15 varied from 2.25 to 5.58 tons, while the corrected yield varied from 11.23 to 19.85 tons, a difference of 8.62 tons per acre in favor of the latter strain, which was also desirable as regards the character of the fruit.

The test of Beauty showed results comparable with those previously tested. Table VII gives the record for the average of the test.

Table VII.—General Average for Beauty, 1909-1910.

Record No.	SOURCE	Av. wt. of marketable fruit	Per cent. of marketable ripe fruit	Yield per acre to Sept. 1st	Corrected yield per acre[1]
1	J. Bolgiano & Son, Baltimore, Md........	.22 Lbs.	78	4.62 T	8.46 T
2	Francis Brill, Hempstead, N. Y...........	.23	73	6.15	10.93
3	H. W. Buckbee, Rockford, Ill.............	.24	72	6.06	12.16
4	H. A. Dreer, Philadelphia, Pa.............	.24	74	7.42	14.83
5	D. M. Ferry & Co., Detroit, Mich........	.23	74	6.92	13.70
6	Griffith & Turner, Baltimore, Md.........	.24	73	7.08	14.13
7	Peter Henderson, New York, N. Y........	.22	79	7.43	14.55
[2]8	Holmes Seed Co., Harrisburg, Pa.........	.27	74	7.78	10.27
[3]9	Leonard Seed Co., Chicago, Ill............	.24	78	10.25	11.33
10	Livingston Seed Co., Columbus, Ohio.....	.22	76	6.00	8.86
11	W. H. Maule, Philadelphia, Pa............	.20	71	5.33	8.33
12	H. F. Michell, Philadelphia, Pa...........	.20	71	4.80	8.16
13	State College	.22	70	5.54	9.06
14	W. P. Stokes, Philadelphia, Pa............	.22	65	4.60	8.57
15	Texas Seed & Floral Co., Dallas, Texas...	.20	72	5.97	10.47
16	J. M. Thorburn, New York, N. Y.........	.23	64	6.28	9.04
17	Webber & Don, New York, N. Y..........	.21	71	4.81	10.02
18	T. W. Wood & Son, Richmond, Va........	.22	66	5.36	12.37
19	Moore & Simon, Philadelphia, Pa.........	.21	65	5.49	12.27
20	Jas. Vick's Sons, Rochester, N. Y.........	.21	64	5.30	12.07
21	W. C. Beckert, Pittsburgh, Pa.............	.22	63	5.02	13.76
[4]22	Wm. Ewing, Montreal, Canada...........	.22	63	5.74	15.17
23	Jos. Harris, Coldwater, N. Y..............	.22	64	6.42	17.47
24	W. W. Rawson, Boston, Mass............	.21	67	4.45	13.03
25	W. Atlee Burpee, Philadelphia, Pa........	.21	59	5.81	16.04

[1] Record for one year.
[2] These were Globe.
[3] These were Earliana.
[4] These were Chalk Jewel.

As regards earliness, it will be seen that the yield per acre to September 1 ranged from 4.45 to 7.42 tons, while the corrected yield varied from 8.16 to 17.47 tons, a difference of 9.31 tons per acre in favor of the better strains. Furthermore, the high yielding strain was true to type and desirable. The variation in the per cent. of marketable fruit is of interest since it ranged from 59 to 79 per cent. Another interesting point concerning this test is that three of the strains proved to be varieties other than those for which they were purchased. These would have proved a decided disappointment had they been grown for a market which demanded the variety Beauty in preference to other varieties.

The next table gives the record for the average of the test of Globe.

Table VIII.—General Average for Globe, 1909-1911.

Record No.	SOURCE	Av. wt. of marketable fruit	Per cent. of marketable ripe fruit	Yield per acre to Sept. 1st	Corrected yield per acre[2]
1	J. Bolgiano & Son, Baltimore, Md........	.27 Lbs.	78	7.77 T	13.66 T
2	Francis Brill, Hempstead, N. Y...........	.28	76	7.53	12.38
3	H. W. Buckbee, Rockford, Ill.............	.23	78	6.31	12.52
[1]4	H. A. Dreer, Philadelphia, Pa.............	.27	85	7.76	17.07
5	D. M. Ferry & Co., Detroit, Mich........	.28	81	9.26	14.22
7	Peter Henderson, New York, N. Y........	.26	83	7.04	12.75
[3]8	Holmes Seed Co., Harrisburg, Pa.........	.22	73	7.99	13.10
9	Leonard Seed Co., Chicago, Ill............	.25	79	8.04	15.39
10	Livingston Seed Co., Columbus, Ohio.....	.27	80	8.79	14.88
11	W. H. Maule, Philadelphia, Pa............	.27	82	9.68	16.74
12	H. F. Michell, Philadelphia, Pa...........	.25	78	7.68	15.92
13	State College	.25	78	6.77	14.22
14	W. P. Stokes, Philadelphia, Pa............	.26	80	8.38	16.31
15	Texas Seed & Floral Co., Dallas, Texas...	.28	81	8.83	18.85
16	J. M. Thorburn, New York, N. Y.........	.30	79	9.54	24.60
17	Webber & Don, New York, N. Y..........	.25	80	9.66	20.81
18	T. W. Wood & Son, Richmond, Va........	.27	83	10.89	23.42
19	Moore & Simon, Philadelphia, Pa..........	.27	79	7.70	19.61
20	Jas. Vick's Sons, Rochester, N. Y..........	.28	78	9.68	19.43
21	W. C. Beckert, Pittsburgh, Pa.............	.26	74	7.38	16.41
22	Wm. Ewing, Montreal, Canada............	.27	82	9.08	25.54
23	Jos. Harris, Coldwater, N. Y..............	.25	81	9.82	20.91
24	W. W. Rawson, Boston, Mass............	.26	77	8.61	18.04

[1] Report for one year.
[2] Average of two years.
[3] These were Beauty.

The above table shows that the size of fruit, when considered for the entire period of the test, was fairly uniform; however, it will be seen that the variation in yield to September 1 ranged from 6.31 to 10.89 tons per acre, while the corrected yield varied from 12.38 to 25.54 tons per acre. The character of the fruit of the high yielding strain was quite desirable. It will also be noted that this strain ranked high in the percentage of the fruit which was marketable.

Table IX gives the record of the average of the test of Stone.

Table IX.—General Average for Stone, 1909-11.

Record No.	SOURCE	Av. wt. of marketable fruit	Per cent. of marketable ripe fruit	Yield per acre to Sept. 1st	Corrected yield per acre*
1	J. Bolgiano & Son, Baltimore, Md........	.26 Lbs.	74	3.52 T	17.84 T
2	Francis Brill, Hempstead, N. Y...........	.27	73	3.15	10.96
3	H. W. Buckbee, Rockford, Ill.............	.24	76	4.26	10.50
4	H. A. Dreer, Philadelphia, Pa.............	.24	76	4.30	15.24
5	D. M. Ferry & Co., Detroit, Mich........	.26	69	2.02	13.31
6	Griffith & Turner, Baltimore, Md.........	.25	66	3.22	13.11
7	Peter Henderson, New York, N. Y........	.23	67	3.02	12.40
8	Holmes Seed Co., Harrisburg, Pa..........	.24	65	2.84	10.93
9	Leonard Seed Co., Chicago, Ill............	.26	79	5.19	13.88
10	Livingston Seed Co., Columbus, Ohio.....	.27	71	3.20	14.10
11	W. H. Maule, Philadelphia, Pa............	.26	74	4.03	15.37
12	H. F. Michell, Philadelphia, Pa...........	.25	72	3.41	14.52
13	State College	.23	73	4.66	13.98
14	W. P. Stokes, Philadelphia, Pa............	.24	69	3.43	13.80
15	Texas Seed & Floral Co., Dallas, Texas...	.23	69	4.49	16.23
16	J. M. Thorburn, New York, N. Y.........	.26	67	3.86	12.80
*17	Webber & Don, New York, N. Y.........	.23	65	4.65	10.53
18	T. W. Wood & Son, Richmond, Va........	.25	69	2.95	14.11
19	Moore & Simon, Philadelphia, Pa.........	.24	69	3.05	14.05
20	Jas. Vick's Sons, Rochester, N. Y..........	.23	65	3.08	14.78
21	W. C. Beckert, Pittsburgh, Pa.............	.25	69	3.02	14.98
22	Wm. Ewing, Montreal, Canada............	.28	66	2.41	12.84
23	Jos. Harris, Coldwater, N. Y..............	.25	72	2.39	13.82
24	W. W. Rawson, Boston, Mass............	.25	72	6.01	13.54
25	W. Atlee Burpee, Philadelphia, Pa........	.26	71	4.18	16.35
26	W. F. Allen, Philadelphia, Pa............	.26	64	4.95	13.94

* Average for two years.

This table shows that there was a considerable variation in earliness, in that the yield to September 1 ranged from 2.02 to 6.01 tons per acre. It is generally conceded that this variety is not considered an early one; however, it is desirable that the crop mature before frost. A study of the per cent. of marketable ripe fruit shows that in no instance was this value more than 79, while it was as low as 64 which was due in a considerable measure to the fact that the strain matured late. It will be seen that the corrected yield ranged from 10.50 to 17.84 tons, a difference of more than 7 tons per acre of marketable fruit.

Conclusion

In the study of the preceding pages, the variations which have been noted are significant of the importance that this factor plays in the profitable production of farm crops. While the experiments have been confined to tomatoes of six varieties, yet there is ample reason to believe that the principle involved is of general application, regardless of the particular kind of crop grown. Thus, whether a person be interested in the production of crops as diverse as the growing of cucumbers under glass or potatoes and corn in large acreages, the possibility of securing a strain superior to the one already being grown continues to exist.

In this test, it has been shown that variations occurred in yield of more than thirteen tons per acre of marketable fruit. These differences must be attributed not to environmental conditions which are improved at considerable expense and which are of short duration, but to heredity, a factor which is more or less persistent and which acts without expense. In view of this fact, the importance of considering the factor of variation should need no further amplification.

At the present time doubtless the best way to be assured of having one's planting prove satisfactory is to secure seed, whenever practicable, a year in advance of the time when it will be needed for general planting and submit it to a preliminary test. By securing several strains, the test will show which is most desirable and the following year the major planting may be made from the lot which proved best in the previous test. It is true that this plan will entail some extra effort and expense, but these are insignificant when compared with the gain from planting a superior strain; that is, one which has proved its superiority under local conditions.

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The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 130

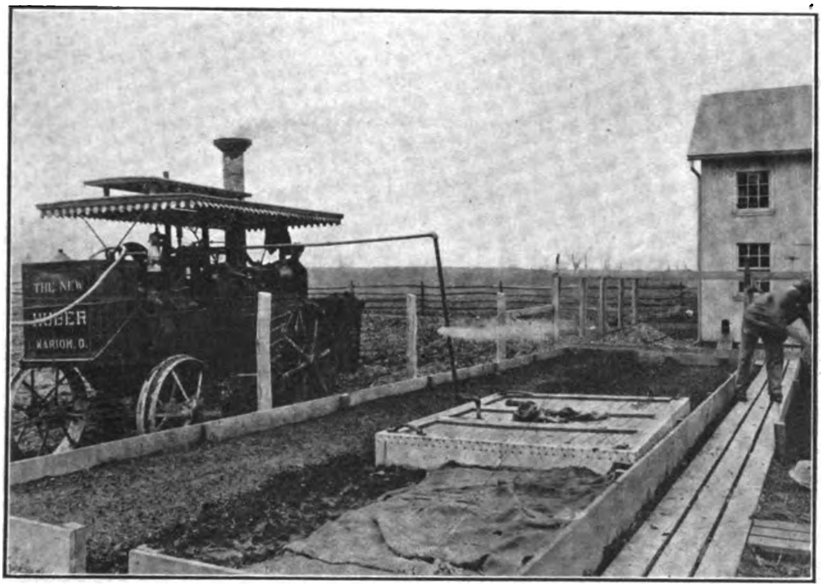

Fig. 1.—Steam Sterilizing Seed-Beds

TOBACCO SEED-BEDS

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The Pennsylvania State College Agricultural Experiment Station

BULLETIN No. 130

TOBACCO SEED-BEDS

By OTTO OLSON
Co-operating Assistant, U. S. Bureau of Plant Industry

Introduction.

The importance of good, healthy tobacco seedlings can hardly be overestimated, because a uniform crop of good quality cannot be obtained unless the young plants are healthy and possess compact, well developed roots. There seems to be a general lack of authentic information, even among experienced tobacco growers, regarding the best methods to follow in order to raise good plants, and contradictory opinions are common. Comparatively little work in an experimental way has been done on tobacco seed-beds, though this phase of tobacco culture offers an inviting field for study. Tobacco plants were very scarce in Lancaster County in 1913, and were in such demand that tobacco growers whose seed-beds had failed were forced to pay as high as $4.00 a thousand for plants,—almost a prohibitive price, when it is considered that from 5,000 to 6,000 plants are required to set one acre of seedleaf tobacco, and nearly twice as many for one acre of Havana tobacco.

Some seed-bed experiments have been conducted at Ephrata for the past two seasons; though they should be carried on for a number of years in order to secure full data, it is believed that the results already obtained will prove interesting and suggestive to the tobacco growers of Pennsylvania.

Table I.—Plan of the Experiments

Frame No.	Fertilizer per acre.	Treatment with steam.	Number of days between sowing and germination.	Color of plants when pulled.	Number of days after sowing required to reach proper size for transplanting.	Notes
1	20,000 lbs. Stable manure. 1,600 lbs. C. S. meal*... 400 lbs. Acid phosphate. 200 lbs. Sul. of potash..	Not sterilized	20	Medium green	73	Numerous weeds. Frame weeded 3 times.
2	20,00 lbs Stable manure.. 1,600 lbs. C. S. meal... 400 lbs. Acid phosphate 200 lbs. Sul. of potash.	Sterilized	18	Dark green	56	No weeds at any time during growth of plants.
3	20,000 lbs. Stable manure. 2,000 lbs. C. S. meal.... 400 lbs. Acid phosphate. 200 lbs. Sul. of potash.	Not sterilized	20	Yellow green	72	Numerous weeds. Frame weeded 4 times.
4	20,000 lbs. Stable manure. 2,000 lbs. C. S. meal..... 400 lbs. Acid phosphate. 200 lbs. Sul. of potash.	Sterilized	18	Dark green	56	No weeds.
5	20,000 lbs. Stable manure. 2,000 lbs. C. S. meal.... 400 lbs. Acid phosphate. 200 lbs. Sul. of potash.	Sterlized	18	Dark green	56	Fertilizers applied after sterilization, causing very slow growth at first. No weeds.
6	No manure. 1,000 lbs. C. S. meal........	Sterilized	18	Yellow green	68	No weeds.
7	No manure. 1,600 lbs. C. S. meal.... 400 lbs. Acid phosphate. 200 lbs. Sul. of potash.	Sterilized	18	Dark green	60	No weeds.
8	20,000 lbs. Stable manure.... 600 lbs. C. S. meal........	Sterilized	18	Light green	68	No weeds.
9	20,000 lbs. Stable manure....	Sterilized	18	Yellow	72	No weeds.
10	20,000 lbs. Stable manure.... 400 lbs. Acid phosphate....	Sterilized	18	Yellow	72	No weeds.
11	No fertilizer used...........	Not sterilized	20	Yellow	110	Numerous weeds.
12	20,000 lbs. Stable manure....	Not sterilized	20	Yellow	83	Numerous weeds.
13	No manure. 1,600 lbs. C. S. meal........	Sterilized	18	Deep green	68	No weeds.
14	No fertilizer used...........	Sterilized	18	Light green	90	No weeds.
15	No fertilizer used...........	Not sterilized	20	Yellow	102	Numerous weeds.
16	20,000 lbs. Stable manure.... 3,000 lbs. C. S. meal........	Sterilized	18	Very dark green	56	No weeds.

*C. S.—Cotton-seed.

Experiments at Ephrata.

The soil on which these experiments were conducted is of the Hagerstown clay loam type, and rather unproductive, due to lack of humus, which also causes the soil to crack upon drying. The soil was spaded to a depth of 5 inches, March 24, 1913, after an application of manure had been made, except in certain cases where no manure was used. The manure was buried completely by the process of spading, and the top soil thoroughly pulverized by repeated raking. The boards forming the cold frames were then put together and a number of partitions made for the many different varieties and types of seed, and for the various experiments. The fertilizers were applied March 31, and thoroughly mixed with the top soil by raking, immediately after which the beds were sterilized by confining steam for 30 minutes under 70 lbs. pressure in a specially constructed pan, in each section of the seed-bed, as described by Hinson and Jenkins. (1).

At the expiration of the period of 30 minutes, the pan was lifted and moved to the next section, and the sterilized portion covered with burlap, so as to hold the heat in the soil as long as possible. It was noted that the temperature of the soil was 200° Fahr. one hour after the removal of the pan, and that certain chemical changes had taken place in the fertilizers.

The beds were sown April 2 with seed which had not been previously sprouted. The seeds were mixed with dry, sifted ashes for convenience in distributing them evenly over the seed-beds. After being sown, the beds were gently pressed with a flat board, and watered thoroughly, whereupon they were covered with muslin supported by wires stretched across the cold-frames and tacked to the sides of the boards. The beds were kept moist until after the plants were 3 weeks old, when less water was used, though the surface of the beds was never allowed to become very dry.

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(1) **Farmers' Bulletin No. 451, U. S. Department of Agriculture.**

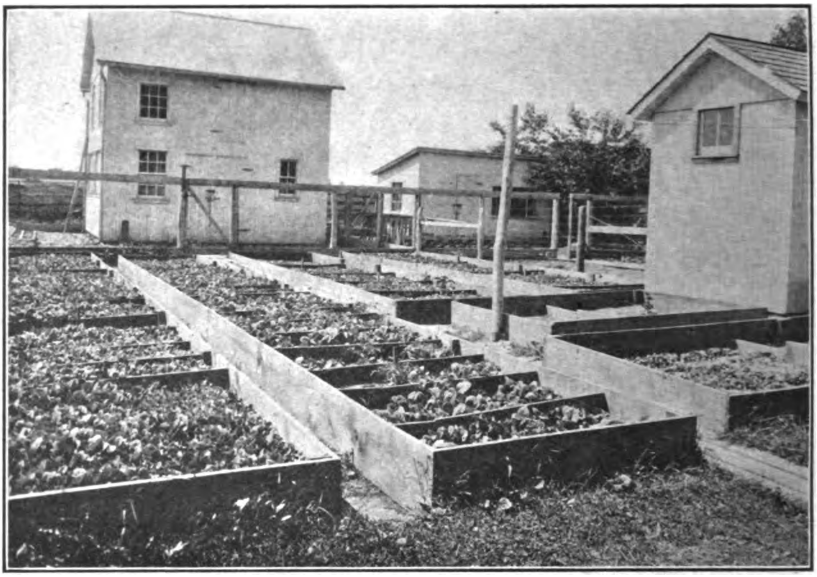

Fig. 2.—Experimental seed-beds at Ephrata. Plants nearly ready for transplanting.

Notes on the Experiment

The Slaughter strain of Pennsylvania Broadleaf was used in all the tests. The seeds had previously been subjected to the cleaning process devised by Mr. A. D. Shamel,(1), by which all light, immature seeds are eliminated and only the heavy seeds retained.

The weather conditions were very unfavorable after the seeds were sown; severe, cold weather occurred on April 6 and 7, and chilly north winds prevailed until April 21, which probably retarded germination.

It is noteworthy that the seeds in all sterilized frames germinated about 2 days before the seeds sown in the unsterilized frames, a result which may have been caused by the sterilized beds retaining the heat. The germination was uniform in all beds.

Weeds began to appear in the unsterilized frames long before the tobacco seeds germinated, while no weeds appeared at any time in the sterilized beds.

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(1) Farmers' Bulletin No. 237, pp. 12-13, U. S. Department of Agriculture.

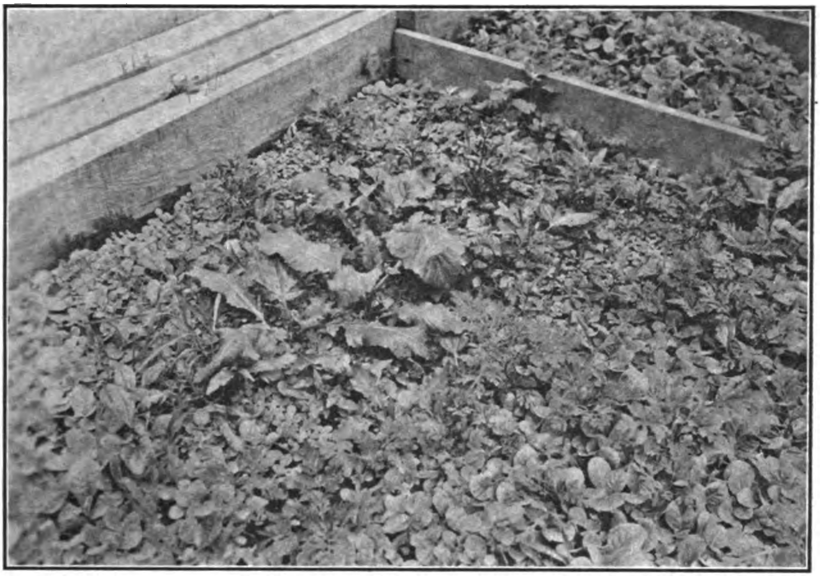

Fig. 3.—This bed was not sterilized. Note the growth of weeds.

The fertilizers in Frame 5 were applied after sterilization, and while germination took place in that frame as early as in the frames in which the fertilizers were applied before sterilization, the subsequent growth of the plants was at first very slow; these plants grew more rapidly, however, later in the season.

The fertilizer tests, while by no means conclusive, show that a well fertilized seed-bed when sterilized may produce plants ready for transplanting in 8 weeks after the sowing of the seed, as shown in Frame 2. It should be noted that all seeds used in these experiments were sown dry, without having been "sprouted" or "swelled," and that the growth of the plants was remarkably uniform, so that when the first pulling of plants took place, 8 weeks after the sowing of the seed, 6,000 plants were pulled in Frame 2, or a sufficient number to plant one acre. The area of the frame was 100 square feet. Larger amounts of fertilizer did not produce plants any sooner, as shown in Frames 4 and 16. A balanced fertilizer, containing the three necessary elements of plant food—nitrogen, potash, and phosphoric acid—gave the best results when applied in moderate quantities, as in Frame 2. It should be borne in mind that the quantities of fertilizers used in these experiments were computed at acre rates.

Owing to the difficulty of obtaining it, hen manure was not used in any of the experiments in 1913, though it was used in a small sterilized bed in the experiments of 1912, and gave good results. The amount used was not weighed, however, and consequently no data can be cited. It is believed that very large quantities of hen manure should not be used.

An Experiment to Determine the Rate at Which Seed Should Be Sown

There is no doubt that many tobacco growers sow the seeds too thickly, a method usually resulting in sickly, yellow plants with long stems, few leaves, and poor roots. On the other hand, when the seeds are sown too sparingly, a much larger area of seed-bed is needed, which of course increases the cost of producing plants. In order, therefore, to ascertain the proper amount of seed to sow without impairing growth or sacrificing space, the following experiment has been conducted for two seasons. Three sterilized frames, each containing 45 square feet, and fertilized with the same quantities of fertilizers, were sown with varying amounts of dry seed, as follows:

Frame 1, sown at the rate of 3 ounces of seed to 900 sq. feet.
Frame 2, sown at the rate of 2 ounces of seed to 900 sq. feet.
Frame 3, sown at the rate of 1 ounce of seed to 900 sq. feet.

One ounce of tobacco seed is said to contain about 300,000 seeds.

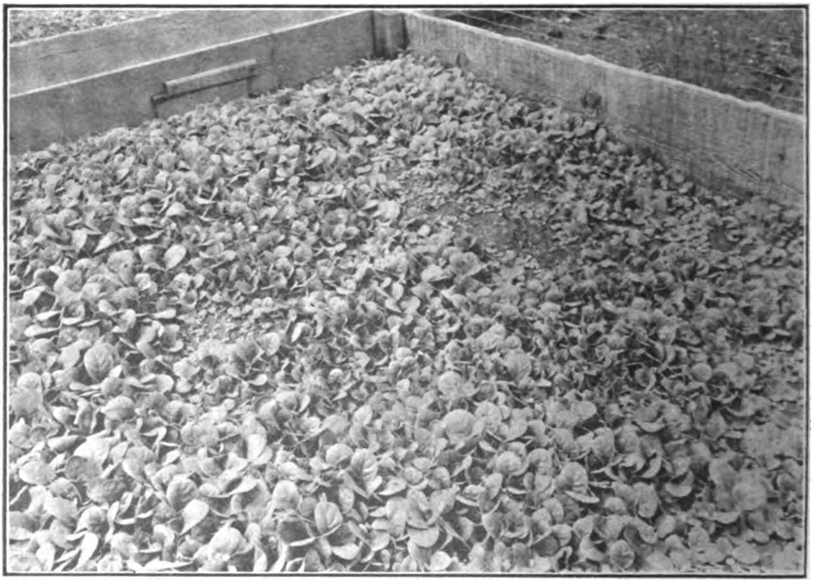

Fig. 4.—Plants on seed-bed on which seeds were sown at the rate of 3 ounces to 900 square feet of seed-bed.

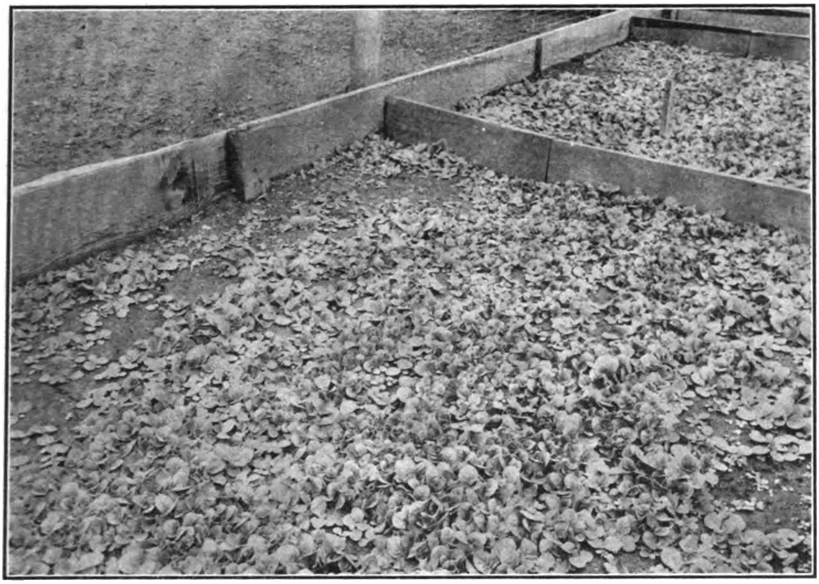

Fig. 5.—Plants on seed-bed on which seeds were sown at the rate of 2 ounces to 900 square feet of seed-bed.

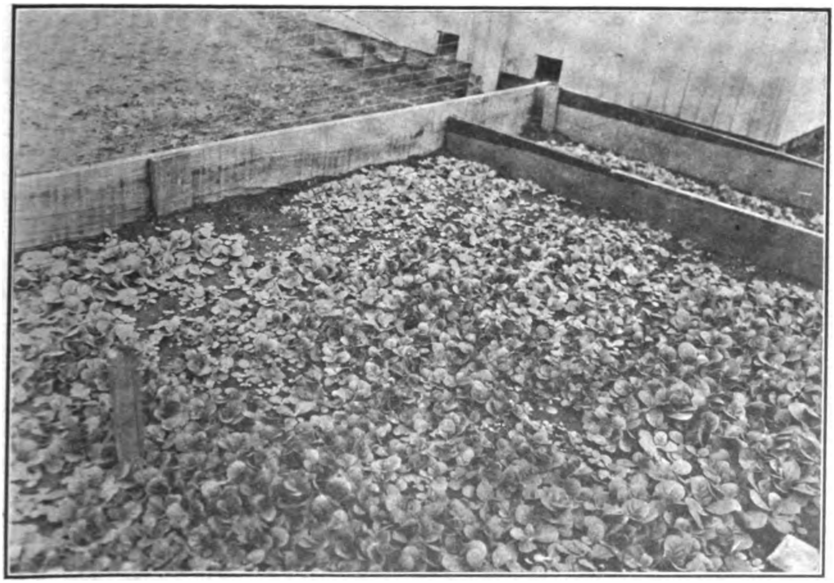

Fig. 6.—Plants on seed-bed on which seeds were sown at the rate of 1 ounce to 900 square feet of seed-bed.

The results were similar in both seasons, and may be briefly described as follows: Plants grown in Frame 1 were of a light green color, had long stems, very few leaves, and short, scanty roots. The plants were evenly distributed over the frame, but were badly crowded, there being about 8 plants to the square inch. Large numbers of plants in this frame died from lack of light and food, and there were several small areas where the plants did not grow at all, but remained yellow and stunted.

Plants grown in Frame 2 were of a medium green color, had few leaves, and fairly good, though small, roots. The stand was somewhat uneven, but averaged about 4 plants to the square inch.

Plants grown in Frame 3 were of a dark green, healthy color, and stocky growth, with spreading leaves and well-developed, bunched roots. The plants were evenly spaced over the frame, about 3 to the square inch.

Benefits of Steam Sterilization

The method of steam sterilization of tobacco seed-beds was devised by Mr. A. D. Shamel, of the Bureau of Plant Industry, and is now successfully used in several of the tobacco-growing states. The apparatus required is a portable boiler, capable of developing and maintaining a steam pressure of 70 to 100 pounds, and steam hose

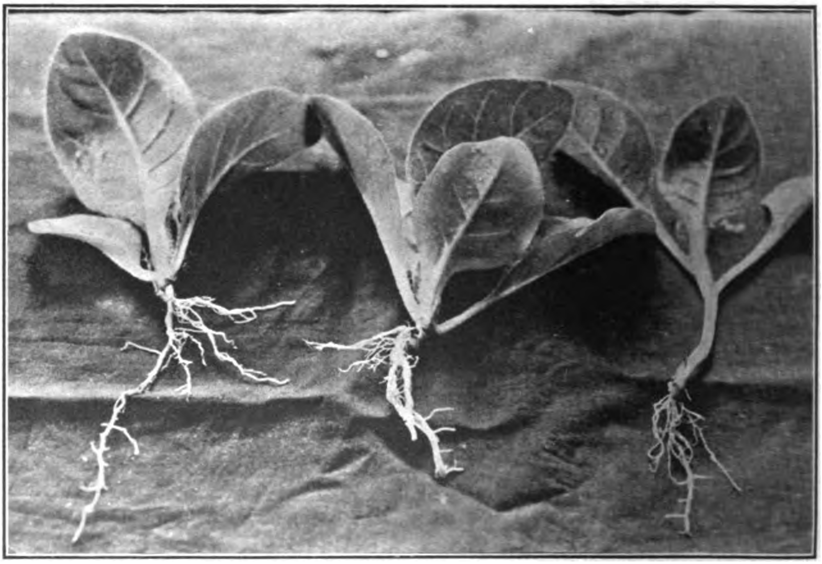

Fig. 7.—Plant on the left from bed seeded at the rate of 2 ounces of seed to 900 square feet of seed-bed. Two plants on the right from bed seeded at rate of 3 ounces to 900 square feet of seed-bed.

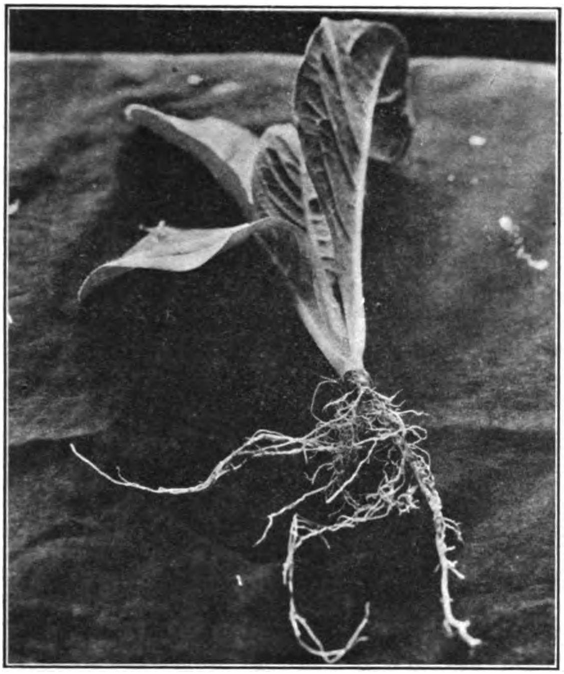

Fig. 8.—Plant from seed-bed on which seed were sown at the rate of 1 ounce to 900 square feet of seed-bed.

or pipe which will stand that pressure, with the necessary connections and the sterilizing pan. The pan is made of 18-gauge galvanized iron; is 10 feet long, 6 feet wide, and 14 inches deep; and has a handle at each corner for convenience in lifting. It is reinforced with strap iron, or can be made over a frame of 2"x4" lumber, for greater rigidity; it is fitted with a nipple for the hose or pipe connection. (See Fig. 1, Title Page).

The seed-bed is fertilized and prepared in the usual manner for the sowing of seed. The steam pan is then placed over a section of the prepared soil, care being taken that the edges of the pan sink into the loose soil, so as to prevent steam from escaping under the edges. The steam is then turned into and confined under the pan, where it rapidly heats the soil. A pressure of at least 70 pounds of steam should be maintained for 30 minutes, after which the pan is moved to the next section. The sterilized section should be covered with burlap, so as to conserve the heat as long as possible.

The benefits due to steam sterilization are many. As a rule, seeds germinate more quickly, and plants develop better, in sterilized than in unsterilized soil. The reason for this was studied by Schulze(1), a German investigator, who found that there are formed during sterilization some decomposition products, which are injurious to a certain extent for a time, but which disappear after a few days; and that there is always an increase in the amount of available nitrogen in sterilized soil due to the action of the heat on the soil compounds; so that while growth in sterilized soil may be retarded for a time, the plants ultimately become more vigorous and the total growth is decidedly greater.

"When (2) the same soil is used season after season, as is usually the case with tobacco seed-beds, it is likely to become so infested with fungi and nematodes that the production of healthy, stocky plants will be impossible. The fungi enter the plant through the roots and cause various forms of drop, wilt, and rot, while the nematodes cause galls on the roots and thus interfere with their function as absorbers and conveyors of water and mineral matter to the plant. Drying and freezing have comparatively little effect on these parasites, and spraying the foliage with fungicide will be of no value, since it does not reach the seat of the trouble, but steam sterilization will effectually destroy fungi and nematodes."

Drs. Russell and Hutchinson, of the Rothamsted Experiment Station in England, have recently investigated the effect upon the bacterial floral of the soil by steam sterilization. They find that bacteria are not the only inhabitants of the soil, but that another group of organisms detrimental to bacteria occur, multiplying more slowly under soil conditions, and possessing lower power of resistance to heat and antiseptics. In consequence of the presence of these detrimental organisms, the number of bacteria in the soil is not dependent merely on the temperature, moisture content, or other conditions of the soil. The number of bacteria depends on the difference in activity of the bacteria and the detrimental organisms. When the soil has been partially sterilized, however, the detrimental organisms are killed, and the bacteria alone are left. It is found that increase in temperature, up to a certain point, favors bacterial multiplication; also that, once the detrimental organisms are killed, the only way to introduce them again is to add unsterilized soil.

Lyon and Bizzell (3) have drawn the following conclusions from the work of various investigators regarding the effects of steam sterilization on soils:

1. The effect on crops: The result of heat sterilization of soil is usually to produce an injurious effect on plants, but this retarding effect is generally overcome after a short time and a decided gain in crop growth finally results from the treatment. This is true

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(1) Landw. Vers. Stat. 65 (1906), No. 1-2, pp. 137-147.

(2) From Farmers' Bulletin No. 296, pp. 11-12, 1907, U. S. Department of Agriculture.

(3) Cornell University Agricultural Experiment Station Bulletin No. 275, p. 132.

of the total dry weight produced as well as of the total nitrogen content of the crop. The favorable influence may extend to the second crop.

2. Effect on the character of the soil: Sterilization increases the solubility of organic matter, nitrogen, and the mineral plant food of soils. Ammonia is formed to a limited extent by the treatment, while carbon dioxid is produced in large quantity. The absorptive power of the soil for water is also increased somewhat.

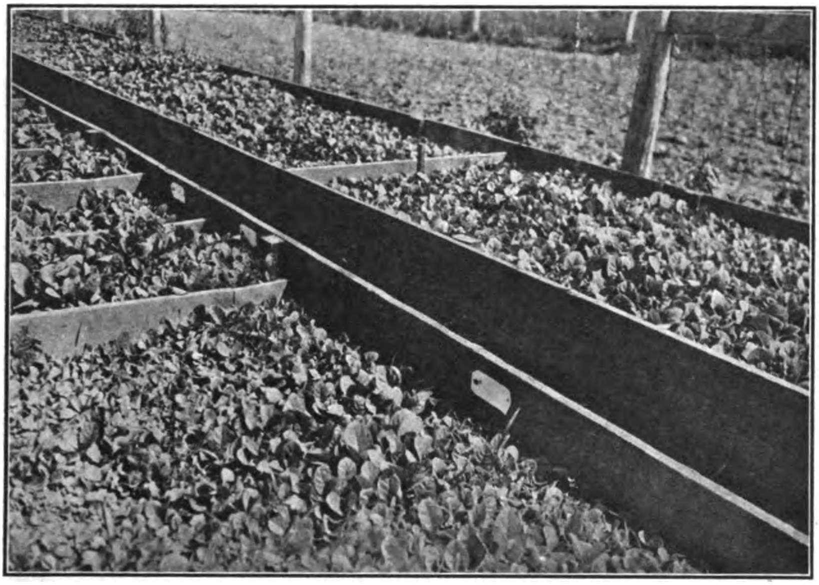

Fig. 9.—Sterilized seed-bed, with plants ready for transplanting.

Construction of Seed-Beds

The same beds may be used for a number of years, if sterilized and otherwise properly cared for; they should therefore be carefully constructed. For convenience in pulling the plants, and in order easily to convert these seed-beds into garden beds after transplanting is done, it is not advisable to make them more than six feet wide, but they may be as long as desired, provided there is no obstruction to the sunlight.

Fertilizers

Tobacco plants are forced to spread their roots widely when growing in an insufficiently fertilized bed. This causes slow growth above the ground, and when the plants are pulled the straggling, spreading roots are damaged, a condition which later interferes with the growth in the field. It is, therefore, advisable to fertilize the beds well, for the reason that the plants will not only grow faster, but the roots will not have to spread out in search of food: they obtain it in a smaller area, and consequently grow in a close, compact bunch, which makes it possible to pull the plant with small loss of rootlets.

The practice in Pennsylvania of spading under manure in seedbeds is an excellent one, because the vegetable matter in it causes the soil to hold and carry water, and supports the bacteria which make nitrogenous manures available. In addition to its fertilizing value, manure also keeps the bed warm. It is advisable, however, to apply a moderate amount of commercial fertilizer as a top dressing just before sterilizing, and to mix it thoroughly with the soil by raking it in well. The following combination gave the best results at Ephrata; it was used on a bed of 108 square feet in area: 48 lbs. manure, 4 lbs. cottonseed meal, 1 lb. acid phosphate, and ½ lb. sulphate of potash. This is equivalent to 20,000 lbs. manure, 1600 lbs. cottonseed meal, 400 lbs. acid phosphate, and 200 lbs. sulphate of potash per acre. This bed when sterilized produced plants ready for transplanting 56 days after the sowing of the seed. Another bed to which the same amount of fertilizer was applied was not sterilized, and the plants required 73 days to become large enough to transplant. These facts show quite clearly that steam sterilization hastens growth.

Sprouting Seed

Forcing the seed to germinate before sowing, or "sprouting," as it is commonly called, is generally practiced by tobacco growers. The object in sprouting seed is to get a somewhat earlier start for the plant, but as Hinson and Jenkins (1) point out, "It is not likely that an early start of the seed at a warm temperature will help it much in the end if the tender sprouts must be put in the cold soil of the bed. It seems more probable that the plant will have a better chance if the seed germinates at somewhere near the temperature it is to have during its early growth. Even if preliminary sprouting will produce earlier plants than dry seeding, it is done at the expense of the general thriftiness of the bed, and to get the crop set in the field very early is rather a doubtful advantage. Cold storms or clear and very cold nights are liable to set back or kill the growing crop. It is a certainty that tobacco will not grow in such cold weather, and when it starts it must grow continuously in order to give a crop of good quality." In one of the experiments at Ephrata, dry seed was sown at the same time as sprouted seed, and while the sprouted seed came up first, the subsequent growth of the plants was no better than in the case of the dry-sown seed.

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(1) Connecticut Agricultural Experiment Station, Bulletin No. 166, pp. 8-9.

Seed-Bed Covering

In order to observe what difference, if any, there would be in the germination and subsequent growth of the plants when covered with muslin and with glass, two parallel beds were selected in the experiments at Ephrata, one covered with muslin and the other with glass. The beds were sown and covered the same day. The seeds sown in the glass-covered bed germinated one day sooner than those sown in the muslin-covered bed; the subsequent growth was slightly faster in the glass-covered bed, the plants being large enough for transplanting nearly one week in advance of the plants in the muslin-covered bed. It is, however, much easier to water a muslin-covered bed, provided the muslin is not too heavy, because the water seeps through, falling like a fine mist on the plants. Watering a glass-covered bed is somewhat laborious, because every sash must be raised in the operation. Muslin is also much cheaper, and with proper care will last several seasons.

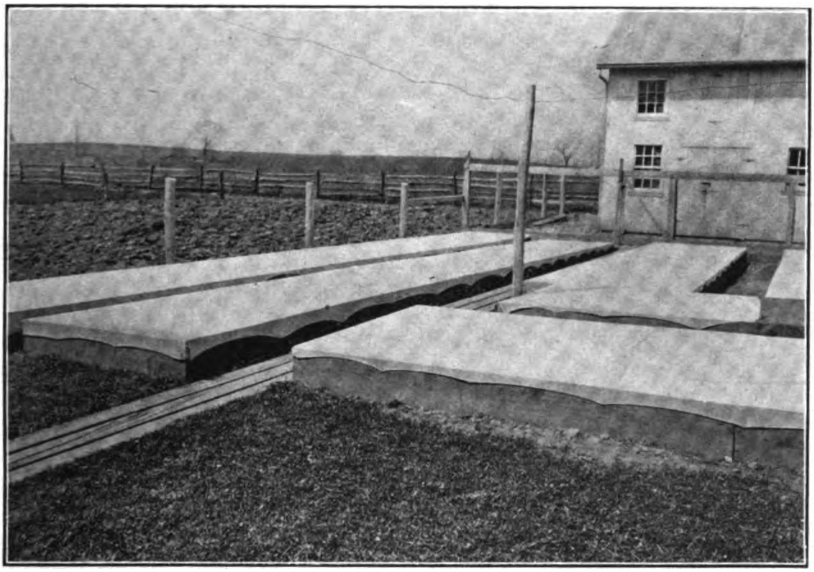

Fig. 10.—Seed-beds after sowing.

Watering and Ventilation

Immediately after the seeds are sown and pressed in, the beds should be watered, and the surface should be kept moist, though not wet, because the seeds need moisture in order to germinate; neglect in watering will cause failure in germination. On the other hand, when the beds are watered too much, the excessive moisture will cause the young plants to rot, and turn yellow, a condition commonly called "damping off." Failure to take off the cover occasionally for ventilation may also result in the development of this disease and other fungous diseases.

Insect Remedies

Insect pests sometimes cause injury to the young plants, and while steam sterilization undoubtedly kills all insects in the bed at the time of sterilizing, it cannot, of course, prevent migratory insects from injuring plants in the seed-bed later in the season. Small insects (1), such as the flea beetle, can be destroyed by the use of arsenate of lead at the rate of 1 pound of arsenate to 20 gallons of water, mixed thoroughly, and sprayed lightly over the plants. This insecticide does not injure the plants in any way, and it adheres to the foliage much better than Paris green.

Snails are causing much trouble in tobacco growing. They can be destroyed by a poison bran mash made as follows: Mix 1 pound of Paris green with 50 pounds of bran and enough molasses to make the mass cohere; add enough water to make a crumbly mixture. Drop small quantities at different points over the bed; care should be taken to keep it from coming into contact with the plants.

Conclusions

Steam sterilization of seed-beds is decidedly beneficial, as it not only effectually kills all weeds and insects when properly done, but also destroys certain detrimental organisms in the soil.

Tobacco seeds should not be sown on the beds until at least 24 hours after sterilization.

Seed-beds should not be too heavily fertilized, but should be well supplied with nitrogen. Stable manure, cottonseed meal, acid phosphate and sulphate of potash, combined in the proportions recommended under the subject of fertilizers, on page 164 of this bulletin, make a good fertilizer mixture. The fertilizers should be applied before sterilizing.

Tobacco seed should be sown without being previously forced to germinate.

Seeds should not be sown too thickly, for too heavy seeding results in crowded plants with poor roots.

Beds covered with muslin are cheaper and easier to water than glass-covered beds, though the latter cause faster growth.

Beds should be ventilated occasionally, and kept moist but not too wet.

When weather conditions permit, covers should be removed about a week before planting time, so as to allow the plants to harden.

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(1) The remedies here given are taken from Year Book Separate 537, entitled "Insect Enemies of Tobacco in the United States," by A. C. Morgan, U. S. Department of Agriculture, 1910.

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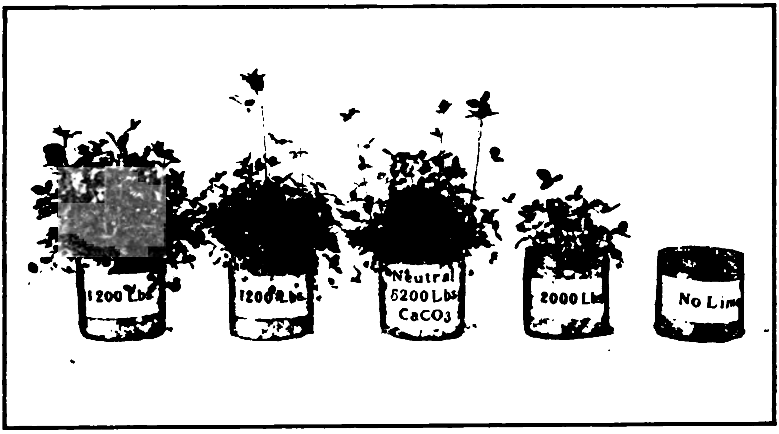
The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 131



A sour soil is unfriendly to clover.
Lime will overcome the difficulty.

THE USE OF LIME ON LAND

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CENTRE COUNTY, PENNSYLVANIA
SEPTEMBER, 1914

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BULLETIN No. 131

THE USE OF LIME ON LAND**

By FRANK D. GARDNER

Our soil experts, in conducting the soil survey of Pennsylvania, found in all parts of the State, and on all of the soil formations, many fields and farms the soils of which were sour. On these acid soils clover fails, and sorrel, red top, plantain, and other plants indicating an acid soil, invade the fields to a very noticeable extent. This sourness of the soil is due to a deficiency in lime and may occur in soils originally rich in lime. Lime is rapidly leached out of the soil and should be replaced when there is evidence of its need. We know of no material cheaper and more effective for correcting soil acidity than lime in one of its several forms.

PENNSYLVANIA SOILS NEED LIME*

Volusia Soils.—The Volusia soils, covering four counties in the northwestern section of the State and ten to twelve counties in the northeastern section, are everywhere in need of lime. "On these soils clover is successfully grown by the few who practice liming or who apply wood ashes. Lime is of great benefit to most of these soils, and should be more extensively used. In fact, the field is probably exceptional that would not be benefitted by at least one application of lime during the course of each crop rotation as now practiced, and if as many green manuring crops were plowed under as should be, for the most economical improvement of the soil, then lime should be applied more frequently to neutralize the extra acid engendered by the decay of the additional organic matter. Such treatment, in conjunction with the application of all the stable manure obtainable, would increase materially the productivity of these soils."

---

*The Reconnoissance Soil Survey of Pennsylvania, in five parts, U. S. Bureau of Soils, discusses the soils, their adaptation, and improvement.

**The writer of this bulletin is indebted to Messrs. B. E. Brown and W. H. MacIntire, at one time Assistants in Soil Research. Most of the laboratory and pot work was done by them. Mr. J. W. White now engaged in similar work has contributed the photographs and certain facts. To Mr. C. F. Noll, in charge Plat Experiments, is due the credit for the data on field tests.

"Lime, organic matter, and, in some cases, drainage are the three fundamental agencies required to double the yield of hay on these soils. Such an increase is a conservative estimate of the capabilities of these soils if treated as suggested."* The Volusia soils are naturally well adapted to grass, and when well cared for, good yields of clover and timothy are secured.

Dairy farming is the leading agricultural pursuit of the Volusia region and the grass crop is the most important both from acreage grown and its influence upon dairying. Wheat is seldom grown, the grass generally being seeded with oats or sometimes with buckwheat. Oats are grown for feed and the straw is used for bedding. Buckwheat and potatoes do well and are the chief money crops. Profitable money crops, good meadows and pastures, and successful dairying are dependent in a large measure upon success with clover. Too many farmers fail to grow enough of this crop. Its failure is generally due to a deficiency of lime in the soil.

Dekalb Soils.—This series of soils, occupying the west-central portion of the State from the northern to the southern border and extending through the east-central portion to the east border, is the most extensive of any in the State. The region is adapted to corn, oats, wheat, buckwheat, potatoes, and grass. In many localities fruits do well. Clover should do well, but in most cases the soils require liming for its growth. In the northern portion of this region this has been tried by very few, and, consequently, many farmers have failed with this crop. Wherever it is impossible to succeed with clovers the highest success with non-leguminous crops cannot be attained.

Westmoreland Soils.—The Westmoreland soils cover about eight counties in the southwestern part of the State. They are similar to the Dekalb soils and differ from them chiefly in their lime content. They are not classified as of limestone origin but are formed from a combination of shales, sandstones and limestones. In general they form a better class of farm lands than the Dekalb soils. This is probably due to their partial limestone origin. Notwithstanding the strata of limestone that enter in their composition, they are very generally in need of lime. Even the Brooks soils, which constitute small areas in the Westmoreland region, resulting from still more limestone, are improved by liming. These soils are so stiff that it is almost impossible to work them satisfactorily unless lime has been used to make them more granular.

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*From the Reconnoissance Soil Survey of Northwestern Pennsylvania.

Hagerstown Soils.—The Hagerstown soils, occurring most extensively in the limestone valleys in the central and southeastern parts of the State, are of limestone origin. So rapidly does limestone dissolve and leach away that the resulting residue in the form of soil may contain no more than a half of one per cent of carbonate of lime. Under constant cropping this is not sufficient to prevent formation of acids in the soil and the accumulation of acids in limestone soils is frequently sufficient to cause a failure of clover. These soils being underlaid with limestone rock, we have close at hand a source of supply that enables us to lime the soil at the minimum of cost.

Miscellaneous Soils.—The Upshur, Berks, Chester, Penn, Lackawanna, Lansdale and other soils of less extent are all more or less in need of lime, and in most sections are benefited by applications of lime.

Sources of Lime.—Few counties in the State are entirely lacking in limestone, although in the extreme southeastern part, along the northern border, and in the northwestern part, exposures of limestone are rarely suitable for development.

In all of the limestone valleys of the State, lime is very abundant and can be secured at low cost. In Beaver County, south of the Ohio River, limestone occurs on the slopes or tops of hills depending on local elevation, and in some cases should be taken advantage of more freely as a source of farm supply.

In the west half of Fayette and Westmoreland Counties, limestone outcrops are frequent and can be cheaply quarried. Coal is frequently found associated with the limestone so that it can be cheaply burned, thus giving lime for the farm at a low cost.

In Clarion County, limestone occurs associated with the shales. In the northern part of Clarion and Jefferson Counties, limestone exposures are not frequent, and are dug only near the bottom of deep-stream cuts. Southward the lime deposits are buried less deeply and lime is cheaper. Prices are frequently as low as $2.00 per ton, which is practically as cheap as a farmer can burn it unless he has exceptional supplies of fuel and labor.

In Clearfield County, the Dekalb soils predominate and but little lime is used; most of it has to be shipped in from outside sources. In this respect Cambria County to the south is in the same class, but Somerset County still farther south has a number of well-developed limestone supplies. The Counties to the east of this are generally well supplied with limestone. In Center and Blair Counties limestone formations are extensive. The extensive quarries and kilns at Bellefonte and Tyrone are sources of supply. It is also a very general practice to burn the limestone on the farm in lime piles.

The Counties in the southeastern part of the State, excepting Philadelphia, Delaware, and the lower parts of Chester and Montgomery are generally near to lime supplies. Over most of this region lime can be secured from local sources, as the outcrops of Ordovician limestone afford extensive supplies of the raw limestone. Lime can usually be purchased at from $1.50 to $3.00 a ton at the numerous local kilns and at a lower figure in car-load lots.

Considerable quantities of hydrated lime, "prepared" lime, and "agricultural" lime are purchased at prices ranging from $6.00 to $9.00 per ton. Usually only small applications of these costly forms are used. At the prices mentioned farmers cannot afford to purchase them when lump lime and ground limestones can be had at less than half the cost.

Where lime is not found for local burning, prices range from $4.00 to $6.50 per ton. Even where facilities for burning lime are good, not more than ten per cent of the land is limed.

In some sections applications of 200 or more bushels of burnt lime per acre are made once in 10 or 20 years. Such heavy applications are often bad for the soil and wasteful of lime. A better method is to apply 25 or 30 bushels every five or six years preferably on the corn or wheat ground. This would keep the soil sweet and yet not burn out the organic matter.

For information on the lime supplies of Pennsylvania, see Bulletin No. 127, Pennsylvania Agricultural Experiment Station.

Crops Require Lime.—Some crops are more tolerant of soil acidity than others. Of our staple farm crops common red clover is about the least tolerant of such a condition. The crops that draw most heavily on the soil here for a supply of lime are those first affected by soil acidity. They are also the least tolerant of soil acidity and generally respond most to applications of lime. The clovers contain much more lime and magnesia than the cereals and grasses. Table I gives the average content of lime and magnesia as carbonates in a ton of the more general farm crops. Notice the large amounts in clover and alfalfa. Common red clover contains more than alsike clover. It is less tolerant of soil acidity than the latter.

TABLE I.—Average Lime and Magnesia, Equivalent to $CaCO_3$ and $MgCO_3$, in 2000 lbs. of the following crops, (Calculated from von Wolff's Tables on the basis of 15% Moisture).

Produce	Pounds of Carbonates as		
	$CaCO_3$	$MgCO_3$	Total
Timothy hay	6.00	2.77	8.77
Wheat (grain and straw)	6.50	6.23	12.73
Corn (grain, cobs and stover)	8.68	8.66	17.34
Oats (grain and straw)	10.40	9.00	19.40
Clover hay (Alasike)	49.00	21.47	70.47
Clover hay (red)	73.00	27.01	100.01
Alfalfa hay	91.00	13.16	104.16

Tolerance to Acidity.—Numerous tests at the Experiment Station show that when the lime requirement of the soil is 1500 to 1700 pounds of burnt or caustic lime per acre seven inches of soil, red clover fails. This is equivalent to from 2700 to 3000 pounds of carbonate of lime or crushed limestone. A lime requirement of 500 to 1000 pounds per acre does not seriously retard the growth of red clover. In ordinary farm practice the acidity seldom becomes sufficiently marked to noticeably affect the cereals and grasses, although these may be indirectly affected by the failure of clover. On our experimental plats where ammonium sulphate has been used, the acidity has become so marked that all of the crops in the rotation are directly affected. The degree of tolerance of these crops is in the following order: oats, wheat, corn, and red clover; the last being the least tolerant of soil acidity.

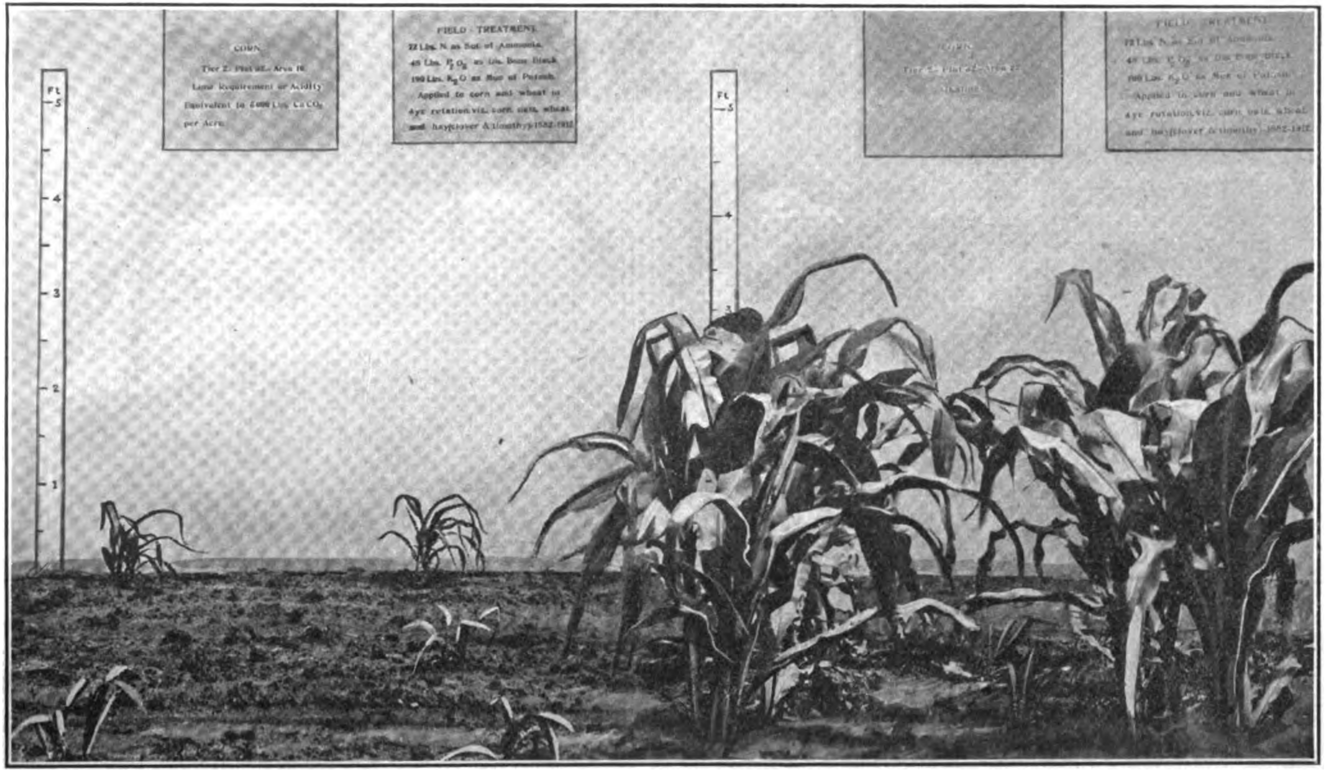

Ft
5
4
3
2
1
CORN
Tier 2. Plot 2E. Area 16
Lime Requirement or Acidity
Equivalent to 5000 Lbs. CaCO₃
per Acre.
FIELD - TREATMENT
22 Lbs. N as Sul. of Ammonia.
45 Lbs. P₂O₅ as Dis. Bone Black
190 Lbs. K₂O as Mur. of Potash.
Applied to corn and wheat in
4yr. rotation viz. corn, oats, wheat
and hay(clover & timothy) 1882-1912
Ft
5
4
3
CORN
FIELD TREATMENT

Plate I. Condition of corn on two areas only ninety feet apart on the same date.

(a) Soil acidity equivalent to 5000 lbs. of $CaCo_3$ is unfriendly to corn.
Plenty of plant food will not overcome it.

(b) Cropped and fertilized the same as (a) for 30 years. Underlying limestone near the surface has prevented acidity.

Carriers of Lime.—Lime is technically known as the oxide of the metallic basic element, calcium. It does not occur in nature in this form, but is prepared by heating limestone in kilns. 100 lbs. of pure limestone thus heated loses 44 lbs. of gas known as carbon-dioxide, and results in 56 lbs. of lime. This 56 lbs. of lime may be slaked with water and will combine with enough water to make 74 lbs. of hydrated lime. Therefore, 1120 lbs. of pure lime equals 1480 lbs. of pure hydrated lime, which equals 2000 lbs. carbonate of lime or pure pulverized limestone. When lime and hydrated lime are exposed to the air they slowly combine with the carbon dioxide of the air until finally reverted to the original form of carbonate of lime. The only difference between the original lime rock and completely air-slaked lime is that of fineness of subdivision, the one being in form of large rock masses and the other a very fine powder. It is this fine state of subdivision that makes air-slaked lime valuable to apply to the soil. If the raw limestone could be made equally fine it would be just as good as such air-slaked lime for the same purpose. If used in generous amounts it need not be so fine as air-slaked lime, but in order to be prompt and effective, pulverized limestone should be so fine that 90% will pass through a 60-mesh screen. Where abundant and cheap, larger amounts of coarser material may be used because of the considerable amounts of finely-divided active material it carries. The coarse portion may become available in later years.

No matter in what form lime is applied to the soil, much of it soon tends to revert to its original form of carbonate of lime.

EXPERIMENTAL TESTS WITH LIME

Pot Tests.—Pot experiments at the Pennsylvania Experiment Station show that finely pulverized raw limestone is just as prompt and effective in correcting soil acidity and promoting the growth of clover as equivalent amounts of caustic lime.

At the close of 30 years the lime requirement of each of the 144 plats in the general fertilizer experiment was determined. Samples of soils were taken from each plat in Tier No. 1, and pot tests with clover conducted on the limed and unlimed soil with the results given in the following table. The results are arranged according to the lime requirement of the soil, and there is given by means of symbols, explained in the foot notes, the field treatment of each of the plats from which soil was taken.

TABLE II.—Weight of Green Clover in Grams. Two Crops from Two Pots. Tier 1, 1910.

Group I. Soil Neutral or Alkaline.

Plat	No. Lime	2,000 lbs. Limestone	Field Treatment
2	20.75	21.00	N. —
3	37.40	35.25	— P.
4	10.95	16.25	— — K.
5	40.95	48.20	N. P. —
8	28.80	33.15	Nothing.
11	42.90	48.15	3N P. K.
12	49.20	47.20	1¼N Pb. K.
15	34.90	37.10	— P. K.
22	38.80	37.80	6M. L. —
23	28.00	24.85	L. — —
34	18.75	18.05	Ls. — —
35	61.75	56.40	1¼N. Pb. K.
Av.	34.43	35.36	

Group 2. Soil Requires O to 500 lbs. CaO per Acre.

Plat	No Lime	Ground Limestone		Slaked Lime Veitch	Lime Requirement, Lbs.	Field Treatment
		Veitch	Veitch+Ton			
1	3.85	2.80	6.00	2.95	182	Nothing.
6	13.60	11.85	13.20	13.05	20	N. — K.
9	35.80	39.80	48.85	42.65	357	N. P. K.
13	5.05	4.80	3.45	4.20	20	Plaster.
14	5.35	6.05	5.70	5.40	21	Nothing.
16	26.30	20.90	21.20	26.80	297	6M. —
25	41.50	43.80	42.10	39.25	338	— P. K.
26	44.40	49.10	52.30	45.65	294	Na. P. K.
27	46.70	46.15	53.25	51.25	109	2Na. P. K.
28	45.40	43.50	45.40	42.05	148	3Na. P. K.
29	39.15	43.40	45.20	38.75	423	— P. K.
33	3.70	3.65	3.50	3.40	151	Plaster.
36	7.15	8.80	10.95	6.50	110	Nothing.
Av.	24.46	24.97	27.01	24.76	190	

Group 3. Soil Requires 500 to 1,000 Lbs. CaO per Acre.

Plat	No Lime	Ground Limestone		Slaked Lime Veitch	Lime Requirement, Lbs.	Field Treatment
		Veitch	Veiteh+Ton			
7	17.55	18.80	20.40	19.50	911	— P. K.
10	41.10	42.65	52.10	48.95	938	2N. P. K.
17	32.20	43.35	48.90	45.25	997	N. P. K.
20	17.65	19.40	24.15	20.60	914	10M.
21	43.85	50.95	57.75	47.85	759	3N. P. K.
24	13.90	15.80	15.15	14.80	668	Nothing.
Av.	27.71	31.83	36.41	32.83	848	

Group 4. Soil Requires 1,000 Lbs. or more CaO per Acre.

Plat	No Lime	Ground Limestone		Slaked Lime Veitch	Lime Requirement, Lbs.	Field Treatment
		Veitch	Veitch+Ton			
18	27.00	32.30	35.50	32.35	1,041	8M.
19	40.85	56.95	54.60	41.25	1,234	2N. P. K.
30	50.80	56.50	64.40	58.50	1,081	Ns. P. K.,
31	3.85	54.90	74.65	67.30	2,086	2Ns. P. K.
32	2.60	46.30	54.20	40.20	1,535	3Ns. P. K.
Av.	25.02	49.39	56.67	47.92	1,395	

N, 1¼N, 2N and 3N=24, 30, 48 and 72 lbs. nitrogen per acre as dried blood.

Na, 2Na and 3Na=24, 48 and 72 lbs. nitrogen per acre as nitrate of soda.

Ns, 2Ns and 3Ns=24, 48 and 72 lbs. nitrogen per acre as sulphate of ammonia.

Pb=48 lbs. phosphoric acid per acre as ground bone.

P=48 lbs. phosphoric acid (P_2O_5) per acre as dissolved bone black.,

K=100 lbs. potash (K_2O) per acre as muriate of potash.

L=4,000 lbs. slaked lime per acre.

Ls=4,000 lbs. finely ground limestone per acre.

M=stable manure, 6, 8 and 10 tons per acre as indicated.

It will be noticed from Table II that Group 1, embracing 12 plats, having the soil neutral or alkaline, gave an average growth of 34.43 grams of green clover from two pots when no lime was applied, and an average green weight of 35.36 grams when 2,000 pounds of ground limestone was applied. In Group 2, embracing 13 plats, having a lime requirement ranging from 0 to 500 pounds per acre, it will be noted that increase in growth for a ton of ground limestone in excess of requirement is relatively somewhat greater than for the first group, but it is a comparatively small increase. Comparing the average effect of ground limestone and slaked lime, when applied in amounts indicated by the Veitch method, we find but very little difference and that slight difference in favor of the ground limestone. In Group 3, embracing 6 plats, having a lime requirement ranging from 500 to 1,000 pounds per acre, the differences resulting from lime are much more marked. In this group however, the slaked lime has given a slightly greater growth than the ground limestone when applied in an equivalent amount. The last group, embracing 5 plats, having a lime requirement of 1,000 pounds or more per acre, shows a very marked increase in the growth of clover following any of the applications of lime. In case of 2,000 pounds of ground limestone in excess of the amount indicated by the Veitch method, the growth of clover is considerably more than double, while it is nearly doubled for each of the other treatments. In this group the ground limestone has again given a greater average growth than the slaked lime, thus indicating that it has been no less prompt and effective in promoting the growth of clover in these pots than an equivalent amount of slaked lime. A careful study of the results of the first and second crops of clover shows that in case of the first crop the difference in favor of the ground limestone was more marked than in case of the second crop, or the average of the two crops. The results indicate, therefore, that the slaked or caustic lime when first applied may have slightly retarded the early growth of the clover as a result of its caustic action. The limestone, however, is not caustic, and would have no such effect. Furthermore, it is easily attacked by even the weakest acids, and wherever the soil is acid in reaction the finely ground limestone, when thoroughly mixed with it, appears to be quite as effective in neutralizing the acidity as the caustic lime would be. In Table II the lime requirement, as determined on June 20, is also given, the requirement being stated as pounds of calcium oxide per acre 7 inches of soil.

LIME REQUIREMENT AND GROWTH OF CLOVER AS RELATED TO FIELD TREATMENT.

In Table III the lime requirement, as related to the field treatment and increase in growth of clover following the application of ground limestone to the pots, is given.

TABLE III.—Lime Requirement as Related to Field Treatment and Increase in Growth of Clover Following Applications of Ground Limestone to Pots at Rate of One Ton in Excess of Requirements.

No. of Plats	Field Treatment	Lime Required per Acre, Lbs., CaO	Wt. Green Clover Grams		Increase or Decrease. Per cent
			No Lime	Limestone	
1	Lime.	00	28.00	24.85	—11
1	P.	00	37.40	35.25	— 6
2	N., Pb., K.	00	55.43	52.80	— 5
1	Limestone.	00	18.75	18.05	— 4
1	Manure and Lime.	00	38.80	37.80	— 3
1	N.	00	20.75	21.90	6
1	N. P.	00	40.95	48.20	18
1	— — K.	00	10.95	16.25	48
1	N. — K.	20	13.60	13.20	— 3
2	Plaster.	85	4.37	3.48	—20
3	Na. P. K.	184	45.50	50.32	11
5	Nothing.	196	11.81	14.28	21
4	— P. K.	210	33.27	36.20	9
6	N. P. K.	714	39.45	51.72	31
3	Manure.	751	23.65	26.95	14
3	Ns. P. K.	1,567	19.08	64.42	238

In Table III the pots from all plats given the same character of fertilizer in the field, have been brought together and averaged, the averages embracing both the average lime requirement as determined by the Veitch method on June 20, and the average green weight of two crops of clover on the pots. The weight of clover, however, is reported only for the unlimed soil and the soil receiving ground limestone at the rate of 2,000 pounds per acre in excess of the requirement as shown by the Veitch determination.

It will be noted that where lime, limestone, and manure and lime, as well as phosphate in the form of ground bone, were applied, the soil is not only neutral or alkaline in reaction, but the average growth of clover in all of these cases was reduced in yield from 3 to 11 per cent by the application of additional ground limestone. There are two instances where the soil was neutral or alkaline in which there has been a marked increase in growth following the application of ground limestone. These instances are in case of one plat to which potash alone was applied, giving an increase of 48 per cent, and the other plat to which dried blood and dissolved bone black were applied, giving an increase of 18 per cent. While the average of two plats receiving land plaster showed a low lime requirement of 85 pounds, there was a marked reduction of yield averaging twenty per cent following the application of the limestone.

Three plats receiving a complete fertilizer, with nitrogen as nitrate of soda, show an average lime requirement of 184 pounds per acre as compared with an average of 714 pounds per acre for 6 plats receiving a complete fertilizer in which nitrogen was applied as dried blood, the potash and phosphoric acid being the same in form and amount as for the three plats mentioned first. The increase in growth resulting from the lime was 11 per cent., where the sodium nitrate was used and 31 per cent where dried blood was used. It should be noted, however, that the clover on the untreated pots gave a considerably lower yield for the dried blood than it did for sodium nitrate, while the addition of the limestone brings the average yield in case of dried blood slightly above that obtained by the lime in the presence of sodium nitrate.

The most striking point in this table is the very high lime requirement of the three plats receiving ammonium sulphate and the very small growth of clover in the absence of lime, with by far the largest average growth when the acidity is corrected by the use of ground limestone. The increase in growth resulting from limestone, as shown in the table, is 238 per cent. The results show now that ground bone tends less to bring about an acid condition of the soil than does the same amount of phosporus in the form of dissolved bone black.

Table IV summarizes the results set forth in Table II and gives the relative growth by groups according to range in lime requirement on the basis of 100 where no lime is applied.

TABLE IV—Relative Growth of Clover as Influenced by Lime; Based on Total Growth from Two Pots and Averaged for the Number of Plats Indicated.

Number of Plats	Av. Lime Required. Lbs.	Relative Green Weight of Clover			
		No Lime	Slaked Lime Veitch	Limestone Veitch	Limestone Veitch+Ton
12	None	100	—	—	103
13	190	100	101	102	110
6	843	100	118	115	131
5	1395	100	192	197	222

Table IV shows an increase in growth for the first group of only 3 per cent resulting from the application of ground limestone at the rate of one ton per acre in excess of the Veitch requirement, with 10 per cent increase for the second group, 31 per cent increase for the third, and 122 per cent increase for the last. It will also be noted that in two out of three instances the limestone has given a larger increase than the slaked lime, with but little difference, however, in the averages.

A study of the tables will show a wide range in the yield of clover on pots from the different plats. The average yield from the pots receiving 2,000 pounds of limestone, in excess of the lime requirement indicated by the Veitch method, on 18 plats making the most satisfactory growth, is equivalent to 48,000 pounds of green clover per acre-foot of soil. This is based on 3,500,000 pounds as the weight of an acre-foot. This shows a draft upon the soil by the clover crop in a period of 8 months that far exceeds that which occurs under field conditions. In what measure this very heavy growth and draft upon the soil has increased the acidity of the soil, and to what extent it was responsible for the acid condition of the soil at the close of the test, in most pots that were treated with lime in amounts just sufficient to neutralize the acidity, is impossible to state.

When the pot experiments were terminated, the contents were removed from the pots and the roots of the clover carefully separated from the soil by passing it through a sieve. The roots were washed, dried, and weighed and the results show a growth associated with lime treatment which closely corresponds to the growth of the tops reported in Table III. Where the lime requirement was greatest, the increase in root growth from liming was somewhat more marked than that of the tops. The dry weight of roots equaled 41 per cent of the dry weight of the roots and tops combined. For one-half of the plats, giving the largest growth when limed, the absolute amount of dry matter in the roots was at the rate of 8,575 pounds of dry matter per acre-foot of soil.

After growing two cuttings of clover, and separating the roots of the same from the soil, the lime requirement was again determined in the same manner as at first. In nearly all of the pots to which lime had been applied in amounts just sufficient to meet the requirements as indicated by the first determination, the soil was found to be still somewhat acid in reaction. Where caustic lime was used, the original acidity has been reduced 71 per cent, and in case of the ground limestone it was reduced 72 per cent. From these results, it is evident that here the lime requirement indicated by the Veitch method falls about one-third short of the actual amount of lime advisable to apply under field conditions. This suggests that a third to a half more of lime should be applied in farm practice than is indicated by the Veitch method if the soil is to be neutral after one or two crops have been grown.

FIELD TESTS

In the general fertilizer experiment referred to in the foregoing pages, there are three plats in each of the four tiers, or twelve plats in all, that have received definite amounts of lime at regular intervals. The limed plats and those with which they are being compared are as follows:

Plat No.	Treatment and Amount per Acre.
16	Manure, 6 tons every two years.
22	Manure, 6 tons, burnt lime, 4000 lbs. every four years.
23	Burnt lime, 4000 lbs. every four years.
24	Nothing.
34	Ground limestone, 4000 lbs. every two years.
36	Nothing.

There are four of each of the above plats, one having the same relative position in each of the four tiers of the experiment. The crops grown consist of corn, oats, wheat, and clover and timothy, each one year. These crops form a four-course rotation so that each year all of the above crops are grown. The manure on Plats 16 and 22 is applied for the corn and wheat, or two applications every four years. The burnt lime is applied for the corn only, or once every four years. The ground limestone is applied to both corn and wheat, or twice in the four years. Since equivalent amounts of burnt lime (CaO) and ground limestone ($CaCo_3$) are to each other as 56 is to 100, respectively, there has been relatively more lime applied in the form of ground limestone. In either case the rate of application has been far in excess of the lime requirement for the soil and it seems probable that one-third or one-fourth as much would have given equally as large increase in yields. Prior to 1908 most of the ground limestone was coarse material, many of the particles being the size of kernels of wheat. The records show no mechancal analysis of the ground stone prior to then. Since that time only fine material has been used, a very large proportion of which would pass a screen of 60 meshes per linear inch.

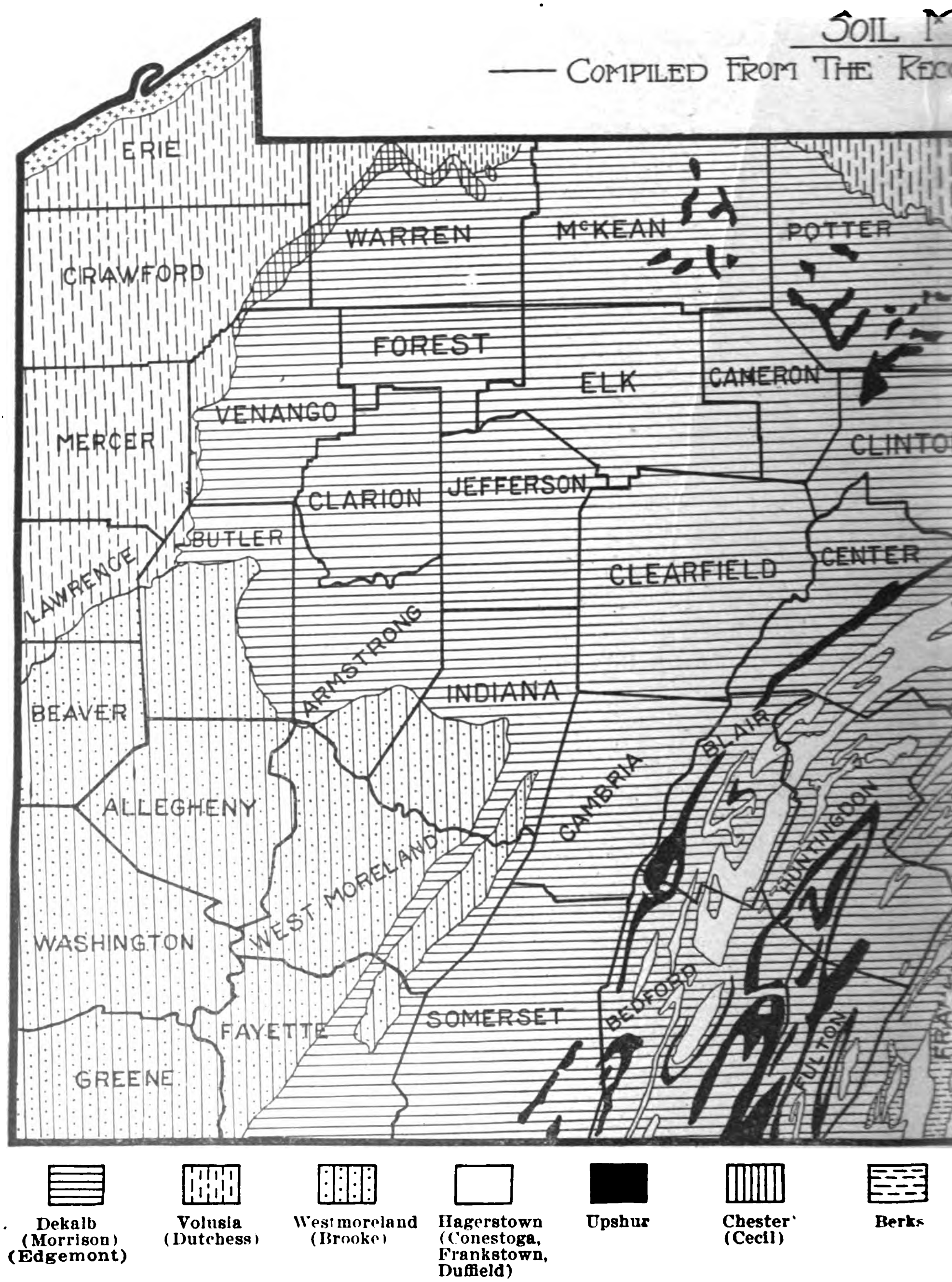
A determination of the lime present in the limed plats, at the close of 30 years, as compared with that in adjacent unlimed plats, shows that, of the total amount applied in that time, only 50 to 60 per cent is now in the upper 21 inches of soil.

The loss of lime from the limed plats has therefore averaged about 750 pounds of carbonate of lime annually. A comparatively small proportion of this is actually withrdrawn from the soil by the crops grown, the greater part of it having leached below the 21 inches of soil analyzed, or having found its way into the drainage waters. The lime and limestone seem to have been leached from the soil with about equal rapidity. The use of 50 bushels of lime every four years is an extreme which does not represent common practice. Except on heavy clay soils, smaller amounts should prove just as effective. 100 bushels or more of caustic lime per acre may retard crop growth the first year after application.

The yields of crops on each of the limed plats for a period of 30 years have been tabulated and reported in the Annual Report of the Pennsylvania State College for 1912-13. In the tabulations, Plats 23, receiving caustic lime, are compared with Plats 24, all of which are adjacent to Plats 23. Plats 34, receiving pulverized limestone are compared with Plats 36, each of which is one plat removed from 34. In case of the lime and manure plats, Nos. 16 and 22, there are five plats intervening.

From the tables referred to, comparing Plats 16, receiving six tons of manure on alternate years, with Plats 22, receiving two tons of caustic lime once in four years, in addition to the manure, we find in the 30 comparisons, for as many years, that lime increased the yield of ear corn in 19 instances, the average annual increase in 30 years being 244 pounds per acre. For corn stover there was an increase only 16 times, with an average annual increase of 16 pounds per acre. Oats were increased 18 times with an average increase of 50 pounds per acre, and oats straw was increased 27 times with an average increase of 316 pounds per acre. Wheat gave an increase 16 times and wheat straw 15 times, with a loss in average yield in both cases of 9 and 56 pounds per acre, respectively. The hay showed an increase 18 times with an average increase of 321 pounds per acre. With corn at 50 cents per bushel, oats at 32 cents, wheat at 80 cents, hay at ten dollars a ton, and two dollars and fifty cents a ton for corn stover, oats straw, and wheat straw, the increase for lime in each rotation would be valued at $4.03 per acre, or a trifle more than $2.00 for each ton of burnt limestone or caustic lime applied. Comparing the effect of lime on the several products, we find the largest relative increase for oats straw, although the absolute increase for hay is slightly greater. Corn ranks third and oats fourth, while both wheat and wheat straw show a small decrease in yield from the lime.

Making similar comparisons for Plats 23, receiving burnt limestone, with Plats 24, receiving nothing, we find only 15 increases for ear corn with an average annual decrease of 129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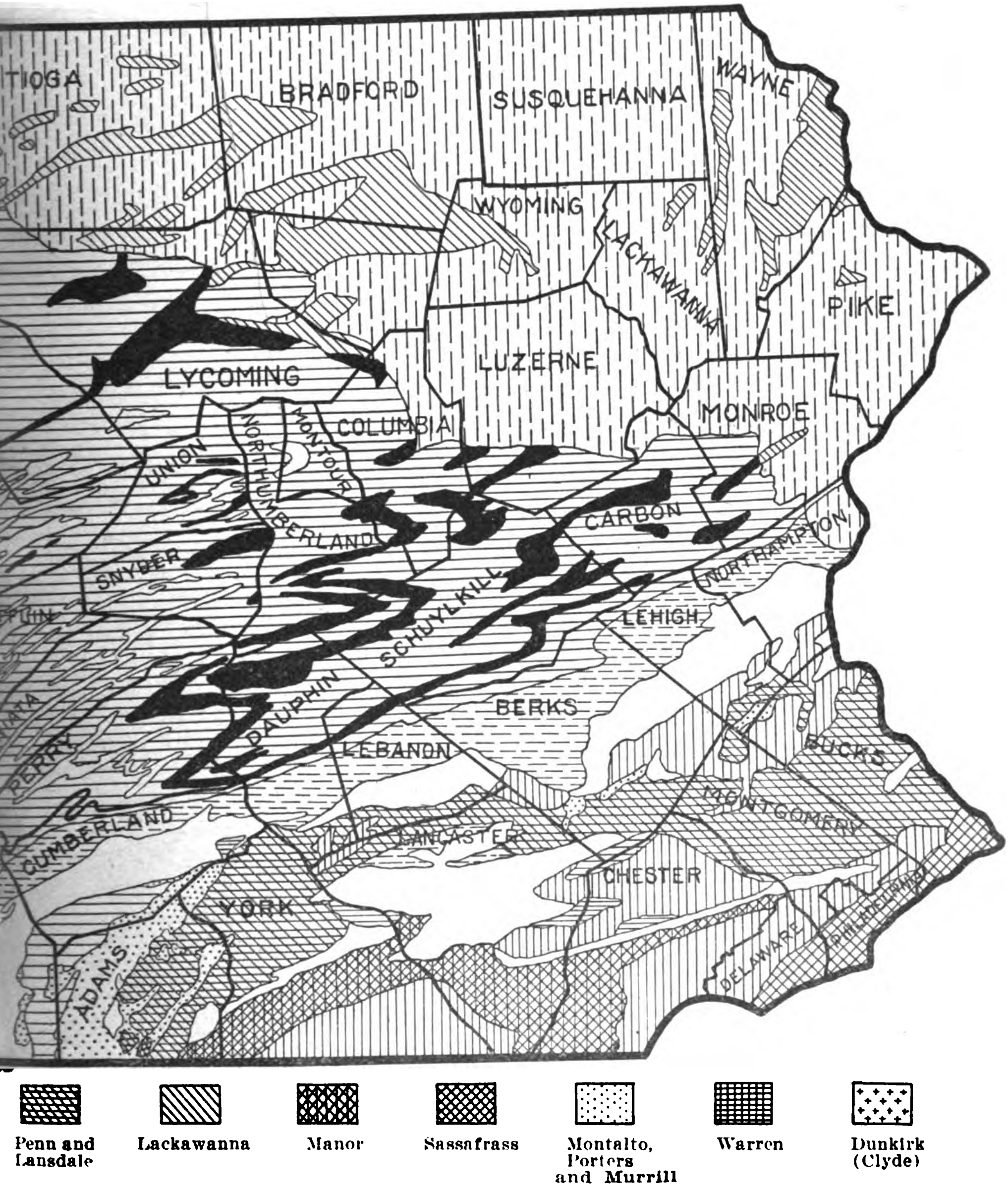

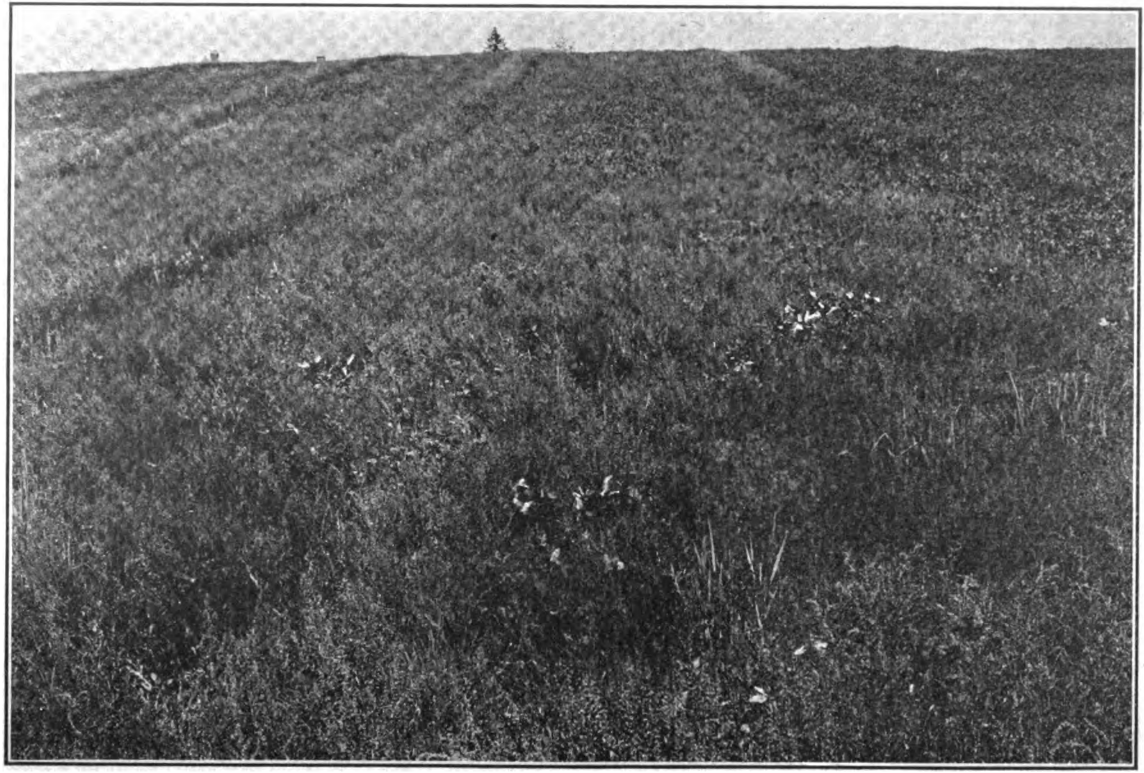

Plate II. Sorrel invades an acid soil and clover disappears.

Plat 31, in centre of picture, receives 48 lbs. nitrogen as ammonium sulphate. Note the luxuriant growth of sorrel and scattering clover.

Plat 30, to right of centre, receives 24 lbs. of nitrogen as ammonium sulphate and growth of clover is still good.

Plat 32, to left of centre, receives 24 lbs. of nitrogen as ammonium sulphate. There is no clover except at a point near upper left hand part where underlying limestone comes near to the surface and has neutralized the acidity.

pounds per acre. For corn stover there was an increase 17 times and an average annual decrease of 5 pounds per acre. Oats showed an increase only 3 times, while the straw showed an increase in all years but two. The oats grain, therefore, shows a reduction of 108 pounds per acre annually, while the straw was increased 376 pounds per acre. Wheat was increased 22 out of 30 times with an average increase of 60 pounds per acre, while the straw was increased 21 times with an average gain of 105 pounds per acre. Out of 29 comparisons for hay, there was an increase only 13 times, but there was an average annual increase of 63 pounds per acre. As in the former comparisons the oats straw is the one product that has been most influenced by lime. All other increases are insignificant and not sufficient to offset the decreases. Using the foregoing values for the several products, instead of an increase for lime, there is an actual reduction of 29 cents per acre in a rotation or 14.5 cents reduction in value of the crops for each ton of burnt limestone applied as compared with an increase of over $2.00 per ton when used with manure. This suggests that burnt limestone, to be most effective, should be used along with manure or organic matter.

Comparing Plats 34, receiving pulverized raw limestone with Plats 36, receiving nothing, we find, for ear corn, that there was an increase 19 times averaging 120 pounds per acre. Corn stover was increased 17 times, the average increase being 24 pounds. Oats was increased 19 times and oats straw 27 times with increases of 57 and 458 pounds per acre for grain and straw, respectively. Wheat and wheat straw were each increased 19 times with average annual gains of 104 and 153 pounds per acre, respectively. The hay showed a gain 16 out of 29 times with an average annual gain of 239 pounds per acre. The average annual increase of 458 pounds of oats straw per acre is a much larger increase than for any of the other products, not only in this but in both of the former comparisons, and confirms what was found in case of the burnt limestone relative to the oats straw being more influenced by lime than any of the other products mentioned. The aggregate average annual increase for all products where raw pulverized limestone was applied is 1155 pounds valued at $4.81 per rotation. This gives a return of $1.20 for each ton of pulverized limestone applied.

Since the check plats, No. 36, with which pulverized limestone is compared, have given average yields exceeded only by check plats No. 8, and check plats No. 24, with which burnt limestone is compared, has given next to the lowest average yield of all checks, it seems as if the above comparisons were conservative. In this comparison we have results that indicate that pulverized raw limestone is superior to burnt limestone as a source of lime for land. The increased yields at the values placed upon the products, however, have scarcely been sufficient to pay for the lime used, whether as crushed raw limestone alone or as burnt limestone with or without manure. The fact that applications of both burnt lime and crushed raw limestone were extreme has lessened the profit as compared with what it would likely have been had smaller applications been made, at less frequent intervals.

Further study of the Tables shows that 6 tons of manure applied on alternate years has fully maintained the yield of corn stover, oats and oats straw during a period of 30 years. In case of wheat, wheat straw, and hay, there has been an appreciable increase during that period, while the ear corn shows a decided falling off in yield, the average for the last five years being 763 pounds or nearly 11 bushels per acre below the average for 30 years. The presence of lime with the manure has fully overcome this decline in case of ear corn, giving an average yield for the last five years of 185 pounds per acre above the 30 years average. It has maintained or increased the yields of all other products.

Plats receiving nothing have nearly maintained the yield of wheat and wheat straw during a period of 30 years, but have declined in yields of all other crops. The same statement holds for plats receiving burnt limestone and raw crushed limestone, except in case of the latter in which there has been a marked reduction in yield of wheat straw. In both of these applications the yield of corn stover has been more than maintained, but the yield of ear corn has declined decidedly.

In order to study the effect of time on the seven products as influenced by lime, the increases (+) and decreases (—) in yield by 5 year averages are tabulated and given below for each of the limed plats.

TABLE V.—Annual Increase (+) or Decrease (—) in Pounds per Acre. Average of Five-Year Periods for Each of Three Limed Plats.

Increase (+) or decrease (—) from	Date	Ear corn	Corn stover	Oats grain	Oats straw	Wheat grain	Wheat straw	Hay
Plats 22 compared with 16	1882-86	—229	—72	+40	+166	—14	—9	+30
	1887-91	+58	—60	+98	+432	—79	—297	—203
	1892-96	—240	—28	+30	+545	+73	+178	+426
	1897-01	+120	+85	+22	+256	+44	+12	+613
	1902-06	+528	+111	+50	+196	—64	—136	+709
	1907-11	+1230	+61	+59	+298	—16	—79	+290
	Av. 30 Yrs.	+244	+16	+50	+316	—9	—56	+321
Plats 23 compared with 24	1882-86	—438	—256	—87	+67	+28	+25	—360
	1887-91	—644	—176	—117	+473	+68	—6	—241
	1892-96	—291	—232	—150	+592	+77	+276	—125
	1897-01	—445	—36	—177	+246	+71	+98	—130
	1902-06	+355	+293	—52	+474	—4	+21	+854
	1907-11	+688	+381	—62	+403	+119	+211	+294
	Av. 30 Yrs.	—129	—5	—108	+376	+60	+105	+63
Plats 34 compared with 36.	1882-86	+39	—56	+71	+420	—126	—127	+95
	1887-91	—378	—176	+3	+516	+142	+429	+116
	1892-96	—155	—332	+130	+645	+213	+317	+26
	1897-01	+350	+229	+8	+259	+147	+347	+193
	1902-06	+444	+109	+83	+384	+107	—12	+572
	1907-11	+423	+370	+45	+523	+144	—34	+404
	Av. 30 Yrs.	+120	+24	+57	+458	+104	+153	+239

It is evident, from Table V, that, with the extension of time, there has been a marked increase in yield of ear corn attributable to lime, whether applied as burnt limestone or as ground raw limestone. This increase during the last two five-year periods has become quite marked. The increases in ear corn are accompanied by increases of less magnitude in corn stover. There is also an increase in hay attributable to lime which increases with extension of time. In case of oats, oats straw, wheat, and wheat straw, there is no noticeable tendency either to an increase or a decrease in yield from lime associated with extension of time. From this table it is evident that oats straw is the product most benefited by the lime. In order to make the relative increases more comparable they have been calculated in percentages and the results are given in Table VI which follows:

TABLE VI.—Percentage Increase (+) or Decrease (—) for Each of the Seven Products for Each of the Lime Treatments. Average of 30 Years.

Product	Plat 22 Burnt lime	Plat 23 Burnt lime	Plat 34 Crushed limestone	Average
Ear corn	+ 6.3	— 5.2	+ 4.7	+ 1.9
Corn stover	+ 0.6	— 0.3	+ 1.3	+ 0.5
Oats	+ 4.0	—10.5	+ 5.6	— 0.3
Oats straw	+17.0	+29.3	+33.0	+26.4
Wheat	— 0.6	+ 7.2	+12.2	+ 6.3
Wheat straw	— 2.3	+ 8.5	+11.7	+ 6.0
Hay	+ 8.1	+ 2.5	+ 9.0	+ 6.5
Average	+ 4.7	+ 4.5	+11.1	+ 6.8

From Table VI it is noticeable again that oats straw is the one product that is most influenced by lime, the average percentage increase in yield for the three treatments being 26.4. This is more than four times as great as that of hay, which gives an average increase in yield of 6.5 per cent. The average relative increases of corn and corn stover and of wheat and wheat straw seem reasonably consistent, but with oats the marked increase in straw is accompanied by a small decrease in grain.

Is it possible that lime has increased nitrification, thus rendering more nitrogen available for the crop? Would increased nitrates have such an effect on the relation of straw to grain?

Determinations of water soluble nitrates in 1910 by Brown and MacIntire show that nitrates in the presence of growing oats are very low during June and July. In that year, for the months of May, June, and July, water soluble nitrates in Plats 22 and 23, receiving lime, averaged a little less than in Plats 16 and 24, with which we are now making comparisons.

From Table VI we also get the average percentage increase for all products, which we find to be 4.5 for burnt limestone alone, 4.7 for burnt limestone with manure and 11.1 for crushed raw limestone.

A SECOND FIELD TEST.

This test was started in 1908 on eight half acre plats on the college farm. This soil is a silty clay loam of limestone origin. For many years the land had been under a four years' rotation of corn, oats, wheat, and timothy and clover, each one year. It had received frequent applications of barnyard manure and was in a fair state of fertility. So far as could be ascertained the soil had received no lime for 27 years. It was in grass in 1907 and the lime was applied to the plowed land when fitted for the corn crop of 1908. Before liming a composite sample of soil was taken and the lime requirement determined by the "Veitch Method." The method indicated a requirement of only 1092 pounds of (CaO) calcium oxid per acre eight inches of soil. The plats were laid out in rectangular form side by side and numbered one to eight inclusive. The treatments were as follows:

Plat No.	**Treatment and rate per Acre.**
1	2544, Exposed lime.
2	Nothing.
3	1676, Exposed lime.
4	2544, Exposed lime.
5	2976, Pulverized raw limestone.
6	1921, Pulverized raw limestone.
7	2544, Exposed lime.
8	4000, Unslaked lime.

The lime was analyzed and it was found that 1676 pounds of exposed lime and 1921 pounds of pulverized raw limestone were each equal to the estimated lime requirement of the soil. These amounts were applied to Plats 3 and 6, respectively. Plats 1, 4, and 7 were used as checks and to each was applied 2544 pounds of exposed lime per acre or about a half more than the indicated lime requirement. Plat 5 received an equivalent amount of limestone or 2976 pounds, while to Plat 8 was applied 4000 pounds of unslaked or caustic lime. Plat 2 received nothing. A mechanical analysis of the pulverized limestone showed that 45 per cent was sufficiently fine to pass through a 1 mm sieve, while 24 per cent was larger than 2 mm. The remaining 31 per cent ranged between 1 and 2 mm. in diameter.

Barnyard manure was applied to the sod a short time before plowing for corn. In 1908 the rate of application was 7 to 8 tons per acre. In 1913 the rate was ten tons per acre. The wheat received 250 pounds per acre of acid phosphate. No other fertilizers were applied. This treatment was uniform over the eight plats. Table VII which follows gives the crops grown and yields obtained from the several plats for the six years, 1908 to 1913, inclusive. The table also gives the increase or decrease in pounds per acre for each plat and product as compared with the check plats, Nos. 1, 4, and 7.

In making the comparisons in Table VII, it is assumed that the natural variation in fertility is gradual and uniform from one check plat to the next. The calculated increase for any treated plat is based on this assumption.

Table VII gives the yield per acre of each crop removed from the eight plats for the six years, 1908 to 1913, inclusive, and the total pounds of products for the six years. It also gives, in **black face,** the increase(+)or decrease(—)per acre for each plat, crop, and year together with the total increase (+) or decrease (—) resulting from treatments differing from the check plats. The yields of corn and timothy hay were very good but the yields of oats, wheat, and clover are below normal for that part of the college farm.

The aggregate reduction in yield per acre from the no lime plat is 499 pounds of products. Putting it in the reverse order, the average increase in yield from check plats, Nos. 1 and 4, over the nothing plat, is 499 pounds, which, at prices given elsewhere in this report, is valued at $2.69. The value of increase is no more than sufficient to pay for the cost of 2544 pounds of exposed lime and its application. It is noticeable that the largest reduction in yield occurs with the timothy crop. This crop was a very satisfactory one, averaging more than two and one-half tons per acre. Plat 3, receiving a smaller amount of lime, shows a decrease in six out of ten times when compared with check plats Nos. 1 and 4. In the aggregate, however, it gave an increase of 497 pounds in six years.

Plat 5, receiving raw ground limestone equivalent to the check plats, shows an increase over the average of checks Nos. 4 and 7 eight times, the aggregate being 991 pounds in favor of the limestone. Plat 6, receiving the smaller amount of ground limestone, gave an increase seven times out of ten with a larger aggregate increase than Plat 5. This is a good showing for ground limestone and marks it as superior to exposed slaked lime in promoting the growth of these crops under the conditions that prevailed in this test. Comparing the increased yields on Plats 5 and 6, with the decreases on Plat 2, we find the values of the difference to be $7.93 and $9.19 for Plats 5 and 6, respectively. This gives a good

TABLE VII.—Actual Yield of Crops in Pounds per Acre as Influenced by Lime in Different Forms and Amounts. Also Increase (+) or Decrease (—) as Compared with Check Plats.

Plat	Lbs. lime applied	Corn, 1908		Oats, 1909		Wheat, 1910		Clover, 1911	Timothy 1912	Corn, 1913		Total Six Years
		Ears	Stover	Grain	Straw	Grain	Straw	Hay	Hay	Ears	Stover	
1	Exposed lime 2544	3485	2668	1020	1140	962	1218	2734	5410	*3517	*3382	25536
2	Nothing	3238	2391	1002	1048	860	1260	2620	4810	3968	4115	25312
	Grain(+)or loss(—)	—212	—217	—41	—189	—102	+42	—120	—470	+508	+301	—499
3	Exposed lime 1676	3590	2534	990	1290	761	1199	2600	5350	3906	4397	26617
	Gain(+)or loss(—)	+176	—13	—75	—45	—201	—19	—145	+200	+502	+150	+497
4	Exposed lime 2544	3379	2487	1088	1432	962	1218	2750	5020	3347	4679	26362
5	Ground limestone 2976	3426	2710	1144	1506	1036	1214	2740	5000	3906	5017	27699
	Gain(+)or loss(—)	+145	+102	+18	+19	+37	—161	+40	—117	+476	+432	+991
6	Ground limestone 1921	3731	2839	1024	1576	970	1540	2730	5180	4092	4735	28417
	Gain(+)or loss(—)	+548	+109	—140	+33	—65	+9	+80	—33	+578	+244	+1363
7	Exposed lime 2544	3085	2851	1202	1598	1072	1688	2600	5310	3597	4397	27400
8	Unslaked lime 4000	3508	2757	1096	1560	1097	1773	2640	5760	3657	†4382	28230
	Gain(+)or loss(—)	+521	—215	—144	—93	—12	—72	+90	+353	—23	+79	+484

*One shock of corn was removed from Plat 1 in 1913, before being weighed. The yield is estimated by weighing remaining shocks.
†Weight of stover estimated as having same ratio to ears as average of Plats 2 to 7, inclusive.

margin of profit on the ground limestone applied. How long the benefits from the application of lime will continue remains to be seen.

Plat 8, receiving the large application of unslaked or caustic lime, gave an increase four out of ten times. In case of ear corn for the first year and timothy, the increase is large and more than offsets the six small decreases.

A THIRD FIELD TEST.

This test was started in 1909 for the purpose of studying the effect of lime in different amounts both as ground raw limestone and as slaked burnt limestone. It comprises 13 one-fourth acre plats in the north corner of Field F, of a run-down farm known as the Thompson farm, which was purchased by the College in 1908. The soil is a silty clay loam of the Hagerstown series. The land has been in cultivation for about 50 years and so far as we can ascertain no lime was ever applied to it. The rotation of crops has generally been corn, oats, wheat, and grass. At time of starting this test the land was in a rather low state of fertility. The amount and form of lime applied to the plats was as follows:

Plat No	Treatment.
1	Check 4000 lbs. exposed lime.
2	Nothing.
3	1980 pounds exposed lime.
4	Check, 4000 lbs. exposed lime.
5	4735 lbs. ground limestone.
6	2343 lbs. ground limestone.
7	Check, 4000 lbs. exposed lime.
8	8000 lbs. exposed lime.
9	9470 lbs. ground limestone.
10	Check, 4000 lbs. exposed lime.
11	24969 lbs. exposed lime.
12	29556 lbs. ground limestone.
13	Check, 4000 lbs. exposed lime.

The 1980 pounds of exposed lime applied to Plat 3 was the lime requirement of the soil as indicated by the Veitch method. Plat 6 received an equivalent amount of ground limestone while the 4735 pounds of ground limestone applied to Plat 5 is equivalent to the exposed lime applied to each of the check plats, Nos. 1, 4, 7, 10, and 13. Plat 8 received 8000 pounds of exposed lime or twice as much as the check plats, and Plat 9 received an equivalent amount of ground limestone. Plats 11 and 12 received exposed lime and ground limestone, respectively, sufficient to bring the lime content of the soil to a depth of seven inches to a total of 1.5 per cent of (CaO) calcium oxide. Ninety-five per cent of the crushed limestone passed through a sieve of 80 meshes to the inch. This is much finer than the crushed stone previously used.

The plowing, preparation of seed-bed, seeding or planting, and the fertilizer and manure applied to these plats was uniform throughout, the only difference being the kind and amount of lime applied. A home-mixed fertilizer, consisting of 50 pounds of nitrate of soda, 350 pounds of acid prosphate, and 100 pounds of muriate of potash per acre was applied for the corn. Ten tons of manure and 350 pounds of the foregoing mixture were used for the barley in which alfalfa was seeded. No other fertilizers were applied.

TABLE VIII.—Actual Yield of Crops in Pounds per Acre as Influenced by Different Amounts of Crushed Raw Limestone and Exposed Burnt Lime.

Plat	Lbs. lime per acre	Yield in Pounds per Acre										Total yield in 5 years	Total gain(+) or loss(—)
		1909—Corn		1910—Barley		1911—Alfalfa†	1912—Alfalfa†			1913—Alfalfa†			
		Ears	Stover	Grain	Straw	One cutting**	1st cutting		3rd cutting	1st cutting	2nd cutting		
1	4000	2548	3833	1176	1824	842	2094	Second cutting not removed.	774	3294	1746	18131	......
2	None	2683	3492	1210	1812	568	2241		544	2858	1460	16868	— 593
3	1980	1940	3620	1108	1564	641	2373		677	3131	1615	16669	— 120
4	4000	1608	3258	998	1324	575	2314		623	3432	1988	16120	......
5	*4735	2551	3876	1190	1812	1014	2441		752	3715	2294	19645	+2549
6	*2343	3083	3790	1200	1912	1148	2392		898	3660	2239	20322	+2249
7	4000	2474	3535	1154	1888	1025	2162		954	3813	2044	19049	......
8	8000	2172	3364	1156	1780	756	2197		933	3279	2226	17863	—1058
9	*9470	2449	3578	1196	2004	974	2235		924	3635	2260	19255	+ 461
10	4000	2223	3309	1104	1816	995	2373		1113	3619	2114	18666	......
11	24969	2003	3003	1164	1876	1064	2387		1240	3688	2151	18576	+ 262
12	*29556	2583	2743	1077	1764	863	2412		1005	3760	2002	18209	+ 247
13	4000	2481	2848	987	1860	996	2373		947	3417	1701	17610	......

*Pulverized raw limestone.

**Crop badly winter killed and was plowed up after cutting and reseeded in August.

†Weights of alfalfa calculated to air-dry basis, 7% moisture. Field cured hay as taken to stack contains 20 to 30 per cent of moisture.

TABLE IX.—Increase (+) or Decrease (—) in Pounds per Acre for Each Crop as Compared with Check Plats.

Plat	Lime applied	Increase(+)or decrease(—) pounds per acre										Total gain(+) or loss(—)
		1909—Corn		1910—Barley		1911—Alfalfa†	1912—Alfalfa†			1913—Alfalfa†		
		Ears	Stover	Grain	Straw	One cutting**	1st cutting		3rd cutting	1st. cutting	2nd cutting	
1	4000	......	......	......	......	......	......	Second cutting not removed.	......	......	......	......
2	none	+448	—149	+ 93	+155	—185	+ 74		—180	—482	—367	— 593
3	1980	+ 19	+170	+ 51	+ 74	— 23	+132		+ 4	—255	—292	— 120
4	4000	......	......	......	......	......	......		......	......	......	......
5	*4735	+654	+526	+140	+300	+289	+178		+ 19	+156	+287	+2549
6	*2343	+898	+347	+ 98	+212	+273	+179		+ 54	— 26	+214	+2249
7	4000	......	......	......	......	......	......		......	......	......	......
8	8000	—218	— 96	+ 19	— 84	—259	— 35		— 74	—469	+159	—1057
9	*9470	+142	+194	+ 75	+164	— 31	— 68		—135	— 49	+169	+ 461
10	4000	......	......	......	......	......	......		......	......	......	......
11	24969	—306	—152	+ 99	+45	+ 69	+ 14		+182	+136	+175	+ 262
12	*29556	+188	—259	+ 51	— 81	—133	+ 39		+ 3	+276	+163	+ 247
13	4000	......	......	......	......	......	......		......	......	......	......

*Pulverized raw limestone.

**Crop badly winter killed and was plowed up after cutting and reseeded in August.

†Weights of alfalfa calculated to air-dry basis, 7% moisture. Field cured hay as taken to stack contains 20 to 30 per cent moisture.

Table VIII gives the yields in pounds per acre secured for each product and plat for the five years 1909 to 1913, inclusive. The alfalfa seeded in barley in 1910 was badly injured by freezing and thawing in its first winter. One cutting was made early in 1911 after which it was plowed up and reseeded in August. The results the following year were more satisfactory as indicated by the first cutting in 1912. The second cutting was so light that it was not removed from the field and the third cutting was also light as shown by the table. The 1913 crop was good, although extremely dry weather made the third crop so light that it was clipped and left on the field. From the last column of the table, it is evident that Plats 5 and 6 treated with ground raw limestone have given the largest total increase in crops. Plat 8, receiving 8000 pounds, gave a decrease in yield as compared with the check plats which receive 4000 pounds exposed lime per acre, and Plat 11, receiving the extra heavy treatment, gave a very small increase.

Table IX, giving the increase (+) or decrease (—) in pounds per acre for each crop, plat, and year, will show more clearly just where and to what extent the growth of the crops has been increased or decreased by the different forms and amounts of lime. The method of comparison is the same as that used in the second field test.

Plat 2 with no lime shows an aggregate decrease of 593 pounds of products in five years as compared with check plats, Nos. 1 and 4, each receiving 4000 pounds per acre of exposed lime. Putting it in the reverse order this amount of lime has increased the yield of crops to the amount mentioned above. With corn at 50 cents a bushel, barley at 72 cents a bushel, corn stover and barley straw at $2.50 a ton, and alfalfa hay at $14.00 a ton, this increase is valued at only $3.20, a sum too small to pay for the amount of lime applied. Plat 8 with 8000 pounds of exposed lime per acre gave a reduction of 1057 pounds as compared with check plats 7 and 10, while Plat 11 with 24,969 pounds gave an aggregate increase of only 262 pounds over check plats 10 and 13. This is a poor showing for the exposed lime in this test.

The only plats showing consistent increases of fair magnitude are Nos. 5 and 6, receiving raw ground limestone in moderate amount. In these two plats there was no crop, excepting the first cutting of alfalfa on No. 6 in 1913, that did not give an increase, the aggregate for the five years being 2549 and 2249 pounds, respectively. With values previously referred to in this article, the average value of increase in yields, on these two plats for the period of five years, is $14.30 and $13.44, respectively. This is more than sufficient to justify the expense of the raw ground limestone applied.

The applications of exposed lime seem to have been slightly depressing to the corn, the reduction in yield of ear corn being most marked for the largest application. The corn was planted 7 to 10 days after applying the lime and it is not improbable that depression of growth might have resulted from the caustic lime added in large amounts. The smaller increases in yield from exceptionally heavy applications of pulverized limestone are also significant and emphasize the uselessness of applying much more lime than is needed to correct the acidity in the soil. Comparing yields from the four rates of application we find that for 1980, 4000, and 8000 pounds of exposed lime the aggregate yield for five years is in favor of equivalent amounts of pulverized limestone to the extent of 2369, 2549, and 1518 pounds per acre, respectively. For the largest application the difference is negligible and the increase over the check plats is very small.

This field test, like both of those previously reported, is favorable to raw pulverized limestone as compared with burnt or caustic lime for application to soils of limestone formation.

SUMMARY OF THE THREE FIELD TESTS.

In the long-continued fertilizer test, the burnt lime alone gave no increase, and pulverized limestone alone gave an increase in crops valued at $1.20 for each ton of limestone used. The average lime requirement of the five plats in Tier 1, receiving no fertilzer for 30 years, given in Table III, is only 196 pounds of CaO per acre seven inches of soil while the average of all acidity determinations for all 20 check plats in the experiment was only 120 pounds. There is little reason to expect large returns from lime when the soil is no more acid than above indicated. From Table III, it will be seen that the lime requirement for all manured plats in Tier I was 751 pounds per acre. The requirement of all plats receiving only 6 tons of manure was 200 pounds. It is possible that the somewhat higher degree of acidity in manure plats is responsible for the larger returns from the burnt lime on such plats. Determinations of humus and nitrogen show the soil of burnt lime plats to be lower in these constituents than either check plats or those treated with limestone.

It is commonly assumed that burnt or caustic lime would destroy some organic matter and result in a loss of soil nitrogen, but whether or not this takes place to an appreciable extent in usual farm practice of liming is open to some doubt.

In the second field test the returns per ton of lime are larger than on the fertilizer plats. There are two reasons for this: First, the soil is more acid, the lime requirement being 1092 pounds of CaO per acre seven inches; second, the initial application of lime was not repeated and the returns are measured over a period of six years. Here the returns per ton of lime applied in case of both burnt lime and limestone have been the largest when used in amounts just sufficient to meet the lime requirement. The returns per ton for burnt lime were $4.25 and $2.12 when the rate of application was 1676 and 2544 pounds, respectively. For limestone it was $9.56 and $5.34 per ton when used at the rate of 1921 and 2976 pounds, respectively. In this test, the returns, excepting for the smallest amount of burnt lime, are quite profitable and are very decidedly in favor of the limestone.

In the third test, the soil is even more acid than in the second, being equivalent to 1312 pounds CaO per acre. The returns from the initial application in this test are for 5 years instead of 6 as in the preceding one, and the failure of the alfalfa in 1911 virtually reduces the time to four years of returns. The returns per ton of material in case of limestone are $11.47 and $6.04 for applications of 2343 and 4735 pounds per acre, respectively. This is slightly larger than in the preceding test. Excessive applications of 9470 and 29,556 pounds of limestone show no benefits from the additional amounts. In fact the returns are less than for the smaller applications. With burnt lime at the rate of 4000 and 1980 pounds per acre, the returns per ton were $1.69 and $1.45, respectively. In this instance not only are the returns very low but they are not consistent with the preceding, in that the smaller amounts gave the lowest return per ton.

All of the field tests are more favorable to the finely crushed limestone than to equivalent amounts of burnt lime. They indicate no advantage in applying much more than sufficient to neutralize the acids present in the soil. Unusually large applications in the third test emphasize the wastefulness of such applications so far as the needs for five or six years are concerned. Large applications may last much longer, how long only long-continued observations on these plats can determine. While these tests are favorable to the finely pulverized limestone, they are not all sufficiently decisive to justify the use of ground limestone at a disproportionate price.

If two tons of ground limestone cost much more than one ton of burnt lime, one would ordinarily not be justified in using the former.

In cases where lime must be shipped some distance, the more concentrated forms are usually the cheaper.

Burnt lime appears to exhaust the humus in the soil more rapidly than ground limestone. Burnt lime with manure gave returns over manure alone. Burnt lime alone gave no increase. It is desirable that the use of lime or limestone lead to larger supplies of organic matter in the soil.

The value of lime in any form depends on its purity and mechanical condition. It should be in such mechanical condition that it can be thoroughly distributed in the soil. The more calcium a given weight of lime contains, the more valuable it is. When the impurities in limestone do not exceed 10 per cent, the limestone and lime may be rated as high grade.

While there may be soils in Pennsylvania that would profit in higher degree from an application of pure lime than from an application of magnesian lime, our present knowledge does not permit us to discriminate against the magnesian lime for use on our farms. It may be as good an investment as a pure calcium lime.

Quantity per Acre.—The amount of lime to apply depends on the degree of acidity of the soil and also on the character of the soil. If a soil is a tenacious clay, and physical improvement is desired, an application of two or three tons of stone lime may be profitable. Ordinarily lime is applied to correct acidity and make a soil friendly to clover and other plants and the equivalent of one to one and one-half tons of stone lime per acre, applied once in each crop rotation, is usually a maximum amount. In some instances 1000 pounds per acre will accomplish the desired result. The equivalent of 1000 pounds of stone lime is between 1300 and 1350 pounds of slaked (hydrated) lime, or a little less than one ton of raw limestone reduced to a powder.

Time of Application.—An application of lime should usually pave the way for clover. It is well to apply lime a year or more before the seeding of clover. If this has not been done, it may be put on the land when the seed-bed is being made for the wheat, oats, or other crop with which clover is to be seeded.

Method of Application.—Lime should be applied after the ground is plowed and thoroughly mixed with the soil by harrowing or disking. The more thoroughly it is mixed with the soil the better and quicker the results will be. It should never be plowed under, because its tendency is to work downward rather than upward in the soil. Apply lime with a spreader after the ground has been plowed. Do not drill lime in with seeds, nor mix it with commercial fertilizer, nor use it in place of fertilizer. Apply lime to meet the lime requirement of a soil, and when this has been done use manure and commercial fertilizers in the ways that have been found profitable for the crops which are to be grown, regardless of the fact that lime has been applied.

The grower of staple farm crops, who does not use a systematic rotation in which clover or some other legume enters, is slowly going into bankruptcy. Land on which clover generally fails, and which produces sorrel and red top instead, will be benefited by the use of lime.

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 132

THE SOILS OF PENNSYLVANIA

By CHARLES F. SHAW

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
OCTOBER, 1914

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BULLETIN No. 132

THE SOILS OF PENNSYLVANIA

By CHARLES F. SHAW

INTRODUCTION

A Reconnoissance Soil Survey of Pennsylvania was started in June, 1908, continued for five years, and completed in September, 1912. In this work, the soil series is shown as the unit on the maps issued, the types in each series being described. This survey has been published in five sections, each representing a season's work: "A Reconnoissance Soil Survey of Northwestern Pennsylvania, 1908," covered 8,112 square miles; "Southwestern Pennsylvania, 1909," covered 7,911 square miles; "South-Central Pennsylvania, 1910," covered 10,908 square miles; "Northeastern Pennsylvania, 1911," covered 7,848 square miles; while the Reconnoissance Soil Survey of Southeastern Pennsylvania, 1912," covered 10,254 square miles, and completed the State.

This paper is a resumé and a brief of the results of that Survey. The accompanying map shows the more extensive and important series, and the report describes those series in brief, presenting also a general statement of their needs and their crop adaptations.

The reconnoissance surveys were made by the U. S. Bureau of Soils and The Pennsylvania State College, in co-operation, and in this paper the writer uses the classification and nomenclature established by the co-operating institutions. In this classification, soils are separated into provinces, series, and types. *"A soil province is an area having the same general physiographic expression in which the soils have been produced by the same forces or groups of forces and throughout which each rock or soil material yields to equal forces, equal results. A soil series is a group of soils having the same range in color, the same character of subsoil, particularly as regards color and structure, broadly the same type of relief and

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*Bulletin 96, Bureau of Soils, p. 7.

drainage, and a common or similar origin." (In short, a group of soils that differ only in texture). "A soil type is a soil which throughout the area of its occurrence has the same texture, color, structure, character of subsoil, general topography, process of derivation and derivation from the same material. A soil class includes all soils having the same texture, such as sandy clays, loams, etc."

The soil province is named in accordance with some general terminology descriptive of the region. The series is named for some town, geographical division, or natural feature near which it is first found (i. e. Westmoreland). The class name is wholly descriptive (i. e. fine sand) while the type name is a combination of the series and class names (Westmoreland fine sand).

Soils are described as "residual" when they are formed by weathering without transportation and occupy the site formerly occupied by the parent rock. Soils are known as "glacial" when formed and transported by the action of moving ice sheets. "Alluvial soils" are those that have been transported and deposited by stream action. "Lacustrine soils" have been transported and deposited in lakes. "Colluvial soils" are those transported by gravity, i. e. talus slopes. These and other terms are used freely in this paper; for further definitions, the reader is referred to textbooks on soils and to the publications of the U. S. Bureau of Soils.

The fertilizer requirements of most of the soils of the state are unknown. For this reason definite recommendations relative to the kinds of fertilizers for the various soils can not be given. The use of manure, green manuring crops, and lime apply to nearly all of the soils and are recommended in nearly all of the soil discussions. On most of the soils such treatments may be advantageously supplemented with commercial fertilizers but the kind and amount that would prove most profitable to use for the different soils and crops should be ascertained by carefully conducted field trials.

The expenditure for fertilizers in Pennsylvania is increasing. At the time of the last census (1910), it was $6,800,000 annually. The intelligent and most economical use of this large annual investment calls for definite information. The Reconnoissance soil survey has emphasized this need and makes possible the intelligent location of field tests for this purpose. Such work will doubtless be inaugurated in the near future

THE SOILS OF PENNSYLVANIA

The State of Pennsylvania is roughly rectangular in shape, about 150 miles in width, north and south, and about 280 miles long, east and west. It lies between parallels 39 degrees 40′ and 42 degrees north, and 75 degrees and 80 degrees 30′ west.

The soils of the State have been classed in seven provinces and forty-seven series. Table I gives the names and extent of each of the series recognized in the reconnoissance soil surveys. Seventy-four per cent of the soils of the State are residual in origin, twenty-two per cent are glacial, while but four per cent are alluvial and lacustrine. Four of the seven provinces—the Coastal Plains, Piedmont Plateau, Allegheny Mountains, and the Limestone Valleys—are residual, while three—the Glacial, Glacial Lake and Terrace, and the River Flood Plains and Terraces, are transported. Of the latter group the Glacial province is the only one of importance.

***TABLE I—Areas of Pennsylvania Soils**

Series	Acres	Per Cent	Series	Acres	Per Cent
Dekalb	12,541,312	43.5	Cecil	39,808	.1
Volusia	5,614,656	19.4	Dutchess	37,312	.1
Westmoreland	2,453,184	8.5	Frankstown	34,368	.1
Hagerstown	1,265,536	4.3	Edgemont	27,328	.1
Upshur	980,663	3.4	Moshannon	25,344	.1
Chester	876,672	3.0	Barbour	24,192	.1
Berks	821,376	2.8	Meadow	19,584	.1
Penn	684,992	2.3	Murrill	15,296	.1
Lackawanna	661,440	2.3	Muck & Swamp	14,592	.1
Manor	320,384	1.1	Duffield	14,400	.1
Brooke	312,768	1.1	Herndon	13,376	.1
Wheeling	299,072	1.0	Schuylkill	12,608	.1
Lansdale	292,032	1.0	Conowingo	9,728	.1
Genesee	239,424	.8	Colyer	9,216	.1
Huntington	225,472	.8	Wheeling	9,216	.1
Chenango	134,208	.4	Lickdale	7,104	.1
Sassafras	127,424	.4	Birdsboro	5,440	.1
Montalto	122,240	.4	Athol	3,904	.1
Porters	117,760	.4	Decatur	2,624	.1
Warren	85,130	.3	Cardiff	1,856	.1
Dunkirk	81,920	.2	Ashe	1,088	.0
Conestoga	76,864	.2	Hanceville	488	.0
Holston	64,448	.2			
Morrison	52,992	.1		28,821,120	100
Jefferson	40,320	.1			

*Compiled from the five reports on the Reconnoissance Soil Survey of Penna.

The state is naturally divided into three physiographic sections. The first section, lying east and south of Blue Mountain, has a generally rolling or undulating to hilly topography, broken by a few irregular, low mountain masses. It includes the Coastal Plains and Piedmont Plateau and a part of the Limestone Valleys and Allegheny Mountain province. The latter province occupies the South Mountains, Welsh Mountains, Reading Hills, and the few other mountain masses of the division. The second section, lying between Blue Mountain and the Allegheny escarpment, is a succession of parallel mountain ridges and valleys— the northern end of the Appalachian mountain system. It includes parts of the Allegheny Mountain, Limestone Valley, and Glacial provinces. The third section, lying west and north of the Allegheny escarpment, occupies a dissected plateau with a topography which varies from rolling to hilly and is mountainous in character. It is occupied by the Allegheny Mountain and Plateau and the Glacial provinces.

The Coastal Plains province has been formed from transported material laid down in estuaries or bays and later elevated above sea-level and the sediments weathered to form soil. The province occurs only in Delaware, Philadelphia, and Berks Counties and consists of a series of low, sloping terraces of slight relief. The Sassafras series is the only one of importance in Pennsylvania in this province.

The Piedmont Plateau province, lying between the "Great Valley" and the Coastal Plains, occupies the larger part of the southeastern counties. The province is broken by the South Mountains, Welsh Mountains, Reading Hills, and by the limestone valleys lying south of these elevations. The Piedmont region has a generally rolling topography with some relatively hilly sections. In this state the Chester, Manor, Penn, and Lansdale series are the most extensive with some areas of Cecil, Montalto, Edgemont, Cardiff and minor series.

The Limestone Valley province is not geographically continuous but includes all the soils derived from limestone rocks. With the exception of the small areas of Brooke soils, the province lies east of the Allegheny escarpment. Topographically, the province occurs as level to rolling or somewhat hilly valleys surrounded by lands lying at considerably higher elevation. The Hagerstown series is by far the most extensive with some small areas of Conestoga, Frankstown, and Duffield soils.

The Appalachian Mountain and Plateau province occurs in two characteristic conditions. South and east of the Allegheny escarpment the mountain section occurs as a series of more or less parallel or coalescing mountain ranges, derived from hard sandstones. separated by relatively narrow valleys derived from shales or soft thin-bedded sandstones. The topography, naturally, is hilly to mountainous. The Plateau section, lying north and west of the escarpment, consists of a much dissected plateau broken by occasional mountain ridges. The plateau region is derived largely from the shales and softer sandstones of the Carboniferous formations, with the mountain ranges derived from the harder Pocono and Pottsville sandstone rocks. The region has a very hilly to mountainous topography with some areas of moderately hilly lands. The Dekalb series is most extensive, though the Westmoreland, Upshur, and Berks soils cover considerable areas, and the Morrison, Porter, and some minor series are found in small areas.

The Glacial province resembles the Appalachian quite closely. Originally the region was occupied by the latter province, but the great continental ice sheet that moved south over this area. modified and altered the soils, subdued the topography, and generally changed conditions. The topography is generally rolling to hilly with some quite mountainous areas. The western portion of the glaciated region has a much smoother topography than the eastern portion. The Volusia and Lackawanna are the leading series in this province with some small areas of Warren and Dutchess.

The Glacial Lake province occurs along the shores of Lake Erie as a series of benches or terraces, representing deposits laid down in Lake Erie during the Glacial period. The Dunkirk and Clyde are the only series found in the State and of these the Dunkirk alone is important.

The River Flood Plains and Terrace province occurs throughout the State, the soils occupying narrow strips along each of the numerous streams. The soils have been formed as alluvial material deposited by the streams, and they occur as level strips subject to overflow—the Flood plains; or as level benches or terraces above overflow—the remnants of old stream deposits that have been left as the river cut its channel to a lower level. The soils, occuring as narrow strips, are nowhere of much importance and nowhere could they be shown on the map. The Holston, Wheeling, Chenango, Huntington, Genesee, Moshannon, Barbour, Schuylkill, and Birdsboro series were recognized. Of these the first four only are developed to an extensive degree.

SASSAFRAS SOILS

The Sassafras soils occupy practically all of the Coastal Plains region of Pennsylvania. Associated with them are a few small areas of the gray, poorly-drained Elkton silt loam; and one or two patches of black or dark gray Portsmouth soils, together with swamp and marsh. These are not extensive enough to warrant description.

The Coastal Plains are represented in Pennsylvania by a narrow strip of soil ranging from three to five miles in width and extending along the Delaware River from a point opposite Trenton southward through Bucks, Philadelphia, and Delaware Counties to the State line. These soils are formed from outwash material deposited as sediment on the sea bottom, reworked and altered by wave and current action, and finally raised above sea-level by continental changes in elevation. The soils are made up of a wide range of material including glacial debris, sandstone, and shale fragments from the mountains to the north, and remnants of granite, gneiss, and other ingneous and metamorphic rocks from the Piedmont Plateau. They are marked by the presence of an appreciable quantity of mica, and frequently contain considerable quartz gravel.

The Sassafras soils have a brown or yellowish brown surface with a yellowish brown to reddish yellow subsoil. The soils are mellow and easily worked, have friable subsoils and, as a rule, are fairly well drained. Small areas of the silt loam and fine sandy loam types, occupying very flat positions, suffer from a lack of adequate drainage. The soils occupy the gently sloping surfaces of low, eroded terraces, extending from the base of the Piedmont hills, at an elevation of about two hundred feet, down to sea-level. The silt loam and fine sandy loams are the most extensive types, with much smaller areas of sandy loam and fine sand. The soils are very well adapted to truck and garden crops but at present are almost wholly devoted to general farming. Corn, wheat, potatoes, and grass are the most common crops. Milk forms the leading source of income on nearly every farm, and there are also several large dairy farms producing certified milk. The soils are well adapted to the needs of dairying, giving good yields of clover and other forage crops, and excellent yields of corn. Pastures "run out" quickly unless carefully handled, and best results are obtained with short rotations, pasturing a field for one year only, using soiling crops to supplement the pasture when necessary.

The soils are normally deficient in lime and on most farms the organic matter content is markedly depleted. Lime should be applied to these soils at the rate of one ton to one and one-half tons per acre, followed by smaller amounts at intervals of four or five years. All of the stable manure made on the farm should be saved and applied to the land, and, in addition, a regular system of green manuring should be followed

The soils are very well adapted to vegetables and to truck and garden farming but, owing to the competition of the lighter soils on the New Jersey side of the Delaware (which bring their vegetables to maturity a week or more ahead of these heavier soils), the gardeners must depend on the larger yield obtained to offset the lower prices that are normal later in the season when their crops reach the market

Land varies widely in value, the latter depending on location. Much of the area covered by these soils is properly suburban and, as such, is held at a price much above its agricultural value.

CHESTER SOILS

The Chester soils comprise one of the most extensive and most important soil series in the Piedmont region of Pennsylvania. The surface soils are typically a yellowish brown to brown color with yellow or reddish yellow subsoils These soils are derived from igneous and metamorphic rocks, principally from gneiss and mica schists, with considerable areas from gabbro diorite and other igneous rocks

The soils occupy rolling to hilly country with a few rather rough, broken areas. The Chester soils lying on the Reading Hills and in the Welsh Mountains are prevailingly hilly to mountainous, with many areas of rough, stony land unfit for agricultural uses.

South of the Chester Valley the soils occupy a rolling to hilly topography, practically all of the land being under tillage. In northern Lancaster and York counties, the soils are moderately hilly with few areas too steep for cultivated crops.

Drainage conditions on these soils are usually good though there are many small areas along the foot of the hills that are kept wet by seepage and that need artificial drainage in order to secure satisfactory yields. The soils are quite retentive of moisture and with proper tillage should carry crops safely through all but the most extended droughts. The soils, largely because of their topography, are subject to erosion and on the steeper slopes, considerable washing and gullying occurs. Sheet erosion (the removal of soil by washing without producing appreciable gullies or cuts) is quite active over most of the area. On the steeper slopes contour farming should be more generally practiced with strips of sod left across the hills when necessary to check the washing.

The most extensive types in the Chester series are the loam and stony loam with the fine sandy loam and mica loam of minor importance. The Chester soils are well adapted to general farming crops. They give excellent yields of corn, wheat and grass, and do well with potatoes and fruit. Truck crops and nursery stock are grown extensively on the lighter soils. Corn is one of the leading crops and excellent yields are obtained. The loam gives the best returns, well-managed fields yielding 75 to 100 bushels per acre. The series, as a rule, will average between 50 and 60 bushels. Ensilage corn is an important crop on the dairy farms.

Wheat does very well on the Chester soils, yields ranging from 18 to 20 bushels on the poorer types and 30 to 40 bushels on the best soils. The average yield is about 25 bushels per acre. Oats are not extensively grown, the yields being rather low, varying from 30 to 40 bushels per acre. Potatoes are a successful crop, yielding from 75 to 175 bushels. With good tillage, care in selection of seed, and proper fertilization, yields of over 200 bushels can be obtained.

Hay crops are among the most important grown on these soils. Clover and timothy are the common grasses, being sown together. The first year's crop is a mixed hay, while the second year nearly pure timothy hay is produced, the clover "running out." Yields average about one and one-half tons but the best fields will yield more than double that amount. Blue grass, red top, and other grasses grow well and make excellent pastures.

With the soils well adapted to corn and grass, and with excellent markets, dairying has come to be one of the most extensive farm industries. The milk may be sold for shipment to the towns or may go to local creameries to be marketed as cream or butter. The dairy herds are generally good and good returns are obtained from their management.

Considerable development of special crops has taken place in these soils. Carnations and other floral plants are grown extensively in some sections; truck crops are important in favorably located regions and tobacco is grown to some extent. Fruit, more especially the apple, is commanding more attention and good results may be expected from well cared for orchards of selected varieties. Peaches do well on the lighter phases of the Chester soils.

The Chester soils are naturally productive and, as a whole, are in excellent condition. The soils are apt to become deficient in organic matter and they respond markedly to applications of manure They are generally benefited by lime and a moderate amount should be applied in the rotation period. Fertilizers are in general use, apparently with satisfacory results. By deep and thorough tillage the liberal use of barnyard manure or green manuring crops, accompanied by periodic applications of lime, and the intelligent use of fertilizers, the soils can be kept in a high state of productivity.

CECIL SOILS

The Cecil soils are of minor extent and importance and have been included with the Chester soils on the map. The soils are derived principally from granites and gneisses and are distinguished from the Chester soils by the grayish red to red color of the soil and the uniformly red color of the subsoil. In crop adaptations and value, they are, in this State, very similar to the Chester soils.

MANOR SOILS

The Manor soils have brown or yellowish brown surface soils with yellow or reddish yellow subsoils. They are derived from the weathering of mica schists and schistose gneisses and characteristically contain a high percentage of mica flakes. Sometimes this mica content increases to such an extent that, at a depth of from 2 to 4 feet, the subsoil is a mass of loose mica particles. Two types are recognized as extensive—the loam and the stony loam. They resemble each other closely, the stony loam being distinguished by the proportion of parent rock in and on the soil mass.

The Manor soils cover a large part of western Chester County, with a strip extending east along the Chester Valley into Montgomery County. They cover a large part of southern Lancaster County and extend across York into Adams County. The soils occupy rolling to hilly topography with steep slopes along streams and with stony, steep-sided ridges. The stony loam type occupies the rougher topography, the loam occurring on the rolling and less hilly areas. The soils are naturally well drained, with water percolating readily through the soil mass. The water-holding ability of these soils is just fair and crops are liable to injury by droughts. This is especially marked in the more micaceous section. The soils wash readily, and damage from erosion is severe unless care is taken to prevent it.

The soils are deficient in organic matter and lime. Clover or other legumes are rarely successful unless lime has been applied but with that amendment, good stands of clover can be obtained. Organic matter, either in the form of green crops or manure worked into the soil, gives a material increase in the yield of crops and also increases the water-holding capacity. Lime and manure with thorough tillage and the control of erosion, work great improvements on the Manor soils. The general farm crops—corn, wheat, oats, and grasses—are grown with some potatoes, buckwheat, and tobacco. Fruit is grown to some extent—apples, peaches, and bush fruits doing quite well where the fertility of the soil is maintained. The soils rank considerably below the Chester series in productivity, though they are adapted to the same crops. Corn will average nearly 50 bushels, oats 35 bushels, wheat 20 to 25 bushels, potatoes about 100 bushels, and hay one ton per acre. With proper management these yields can be materially increased and in many cases doubled.

PENN AND LANSDALE SOILS

The Penn and Lansdale soils are extremely developed throughout the Piedmont region, extending in a continuous belt of varying width across the southern counties, from the Delaware River above Trenton, southeast across the Adams County line, and on into Maryland. The soils are derived from sedimentary rocks, mainly shales and thin-bedded sandstones. The two series resemble each other closely in all respects except color.

The Penn soils have a reddish brown to Indian red surface soil with a dark reddish brown to Indian red subsoil. The Lansdale soils have a brown, drab or dark gray soil with a yellow, drab or mottled subsoil. The subsoils of each series become heavier with depth, usually grading to a silty clay loam and at from 3 to 5 feet usually contain considerable amounts of broken rock, grading into the parent rock at moderate depths.

The soils occupy rolling to moderately hilly country with many nearly level areas. In southern Lehigh County, in Berks County, and in northern Montgomery County, some hilly areas with rough, stony slopes are found.

The silt loam is the leading type in each series while the loam is a quite extensive type in the Penn series. The other types found are of minor importance. The silt loams occupy the more level positions and a large proportion in each series is naturally poorly drained. The Penn loam is generally in better condition but in many sections is materially benefited by tile drainage.

The soils are well adapted to the general farm crops. On the silt loam and loam types of both series, corn, wheat, and grasses do very well. On well drained areas potatoes are quite successful and, with the proper system of culture, can be made a very profitable crop. Apples and peaches do well on the shale loam and stony loam types and on the other types when drainage is good. Tobacco, buckwheat, and oats are crops that are grown to some extent. Tobacco could be made an important crop if the proper varieties are grown and the necessary facilities for curing and handling were available.

The future of the Penn and Lansdale soils lies in the development of fruit growing on the lighter, better drained areas and in the development of dairying on the heavier soils. Corn (for ensilage or grain), wheat, clover, and the grasses, and alfalfa, will be the leading crops, with potatoes as an important money crop on many farms

The soils are deficient in organic matter and are uniformly in need of lime. With applications of lime the soils can be made to produce clover, cowpeas, soy beans, and similar leguminous crops that can be plowed under to supply organic matter. Systematic crop rotation including the frequent production of legume crops is essential in connection with the intelligent use of lime and plant food for the upbuilding of these soils.

MONTALTO, PORTERS, AND MURRILL

The Montalto, Porters, and Murrill soils, with some other series of minor extent and importance, have been grouped together on the accompanying map. The soils are all found on the top or flanks of South Mountain, the Reading Hills, and the Welsh Mountains. Each of the series is adapted to the production of fruit, particularly to apples, and together they form one of the most important apple sections in the state.

Montalto Soils: The Montalto soils have a reddish brown to yellowish red surface, with a subsoil of a similar color. The soils are derived from trap rocks and are locally known as "ironstone" lands. They are sticky when wet but crumble readily when dry. The soils are normally well drained, have a good water-holding capacity, and a fair amount of humus. The stony loam is the most extensive type, with considerable areas of loam. The stony loam contains from 40 to 60 per cent of angular ironstone or cherty fragments. The soils give good results with the staple crops, corn, wheat, and grass, but are primarily adapted to the production of apples and peaches. The coloring and quality of the fruit grown on these soils is excellent, and high prices are obtained for the product of the orchards.

Murrill Soils: The Murrill soils are not extensively developed in the state, being found only in Franklin and Cumberland counties, along the west flank of South Mountain. The soils are similar in appearance to the Montalto soils but have a heavier subsoil. They are underlaid by limestone and in many cases the subsoil material is largely of limestone origin. The soils occupy a sloping position and are marked by a dimpled or pitted topography due to the presence of many small sink holes. The loam type is the most extensive, with considerable areas of stony loam and sandy loam. The soils have a reddish yellow surface soil with a reddish yellow to red subsoil of heavier texture. They are well drained but not droughty. The soils are well adapted to the general farm crops and to apples and other fruits. Though not now as highly esteemed as the Montalto soils, they are nearly as productive and will prove of greater importance as the fruit industry is extended.

Porter Soils: The Porter soils are derived from igneous and metamorphic rocks, mostly quartzites, gneisses and granites. The soils are grayish red to red with red subsoils. They occupy hilly to mountainous topography with the stony loam the most important soil type. The soils, because of their topographic position, are hard to cultivate but where tillable give good results with the usual farm crops, and excellent returns when planted to apples. Fruit of excellent quality, is produced on these soils and, with the good yields obtained, makes the series primarily adapted to this industry. The soils are normally well drained and fairly well supplied with organic matter.

The three series described—the Montalto, Murrill, and Potter—are primary fruit soils and will become of increasing importance as the apple and peach industry is extended.

HAGERSTOWN SERIES

The Hagerstown soils have a yellowish brown to reddish brown surface with a yellow or reddish subsoil. The deeper subsoil usually grades into a red clay before the underlying rock is encountered. The soils are the result of solution and weathering of the Trenton limestone and represent the insoluble residue after the carbonates in the original rock have been dissolved and carried away. The soil mass usually rests on the unchanged limestone rock with no partially decayed or disintergrated rock layer between the true soil and solid rock. A small but important portion of the Hagerstown soils in this State is derived from the Lower Helderberg limestones. This latter formation occurs as a relatively thin layer and is exposed where the folding of the country rock is severe. The Lower Helderberg formation outcrops as long, narrow ridges, giving very narrow bands of Hagerstown soil Associated with these soils are the Frankstown series which usually occupy about one-half of the ridge. The narrow bands of Hagerstown soils are rarely of much agricultural importance in the counties where they occur, but, as lime is almost a universal need on the soils of this state, the outcropping of these limestones afford a readily available source of this important material. These narrow belts of limestone soil are found in the counties lying south and east of the Allegheny escarpment and north of the Great Valley, and wherever possible are shown on the accompanying map.

The large areas of Hagerstown soils are derived from the Trenton limestones. The most extensive body lies south and east of the Blue Ridge (locally known in this state as Kittatinny, First, or Tuscarora mountain) as a valley ranging from four to twenty miles in width and extending across Northampton, Lehigh, Berks, Lebanon, Dauphin, Cumberland, and Franklin counties. The valley extends south into Maryland and Virginia under the names of Cumberland and Shenandoah Valleys. The next largest area is the Lancaster Valley, extending across that county and into the counties to the east and west. Smaller areas are found in York County, Chester County, in the Nittany Valley of Centre and Clinton counties, Morrison's Cove in Blair County, and in Kishacoquillas, Sugar, Nippenose, Black Log, and other smaller valleys in the Appalachian mountain regions.

The soils occupy undulating to gently rolling topography with many nearly level areas. In the Appalachian mountain regions there are some occurences of these soils that are rather hilly, and, as has been previously stated, the long, narrow band derived from the Lower Helderberg occupies rather steep-sided ridges. Drainage conditions are excellent throughout the entire area. In most cases the water soaks down through the soil mass and escapes into the regional drainage system through underground channels that have been dissolved in the limestone rock. Sink holes are common and form a characteristic feature of the topography. Erosion is a negligible factor except on the few steep slopes and on the ridges, and even in such positions is rarely severe. The leading types are a clay loam and silt loam, with the loam, clay and stony loam of less importance. There are practically no areas of sandy Hagerstown soil in this state.

The soils are very well adapted to the production of the staple farm crops, corn, wheat, and grass, and give good results with oats, potatoes, and buckwheat. In Lancaster and York counties, tobacco is a very important crop. About five-sixths of the total tobacco crop in Pennsylvania is raised in these two counties and nearly all is grown on the Hagerstown soils. The yields of corn and wheat are high and the crops are very profitable. Clover crops grow well and timothy gives excellent returns. Alfalfa is found to be well adapted to the soils, excellent returns being obtained whereever sufficient care was taken to insure a good stand. Some fruit is grown and fairly good results are obtained with certain varieties of apples. Although they are derived from a limestone and are usually in a better condition than most of the soils encountered in the State, the soils are benefited by applications of lime, and that amendment should be applied in moderate amounts about once in every rotation period. The soils are benefited by deep tillage and the organic matter content must be maintained in order to keep the physical condition satisfactory. These soils are considered the most productive in the State and have a higher agricultural value than any of the other soils. They are uniformly in a high state of cultivation with excellent farm buildings, fences, and with well equipped farmsteads. The limestone valleys of Pennsylvania are noted throughout the country as among the most productive and prosperous of our agricultural communities.

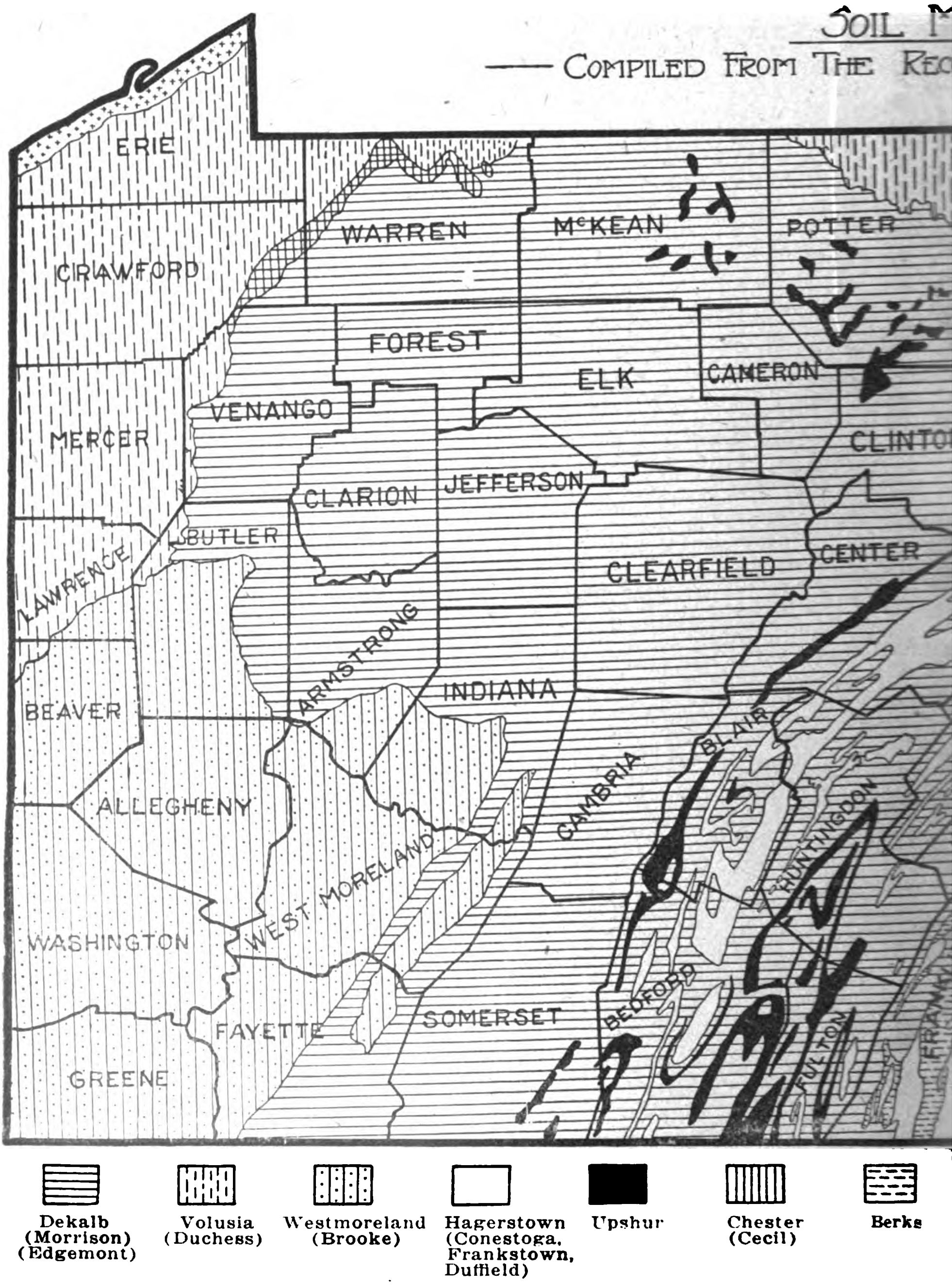
CONESTOGA SOILS

The Conestoga soils are not shown on the map but are grouped with the Hagerstown which they very closely resemble. They are derived from limestone, schistose limestones, and micaceous calcareous shales. They are characterized by the presence of considerable amounts of mica in a finely divided state, giving to the soil mass a smooth rather soapy feeling. The soils have a yellowish brown to brown color with a yellowish or reddish subsoil. They are found in a considerable body lying south of the city of Lancaster between the Hagerstown soils and the higher lying Manor soils. Other bodies of Conestoga soils are found in York and Chester counties. They occupy rolling to moderately hilly topography and normally have good drainage. Erosion is not severe, although on the steep slopes it is quite noticeable.

These soils are adapted to practically the same crops as the Hagerstown and generally give yields but little lower than those obtained from the Hagerstown soils. Potatoes do rather better on the Conestoga soils, giving a much better quality and somewhat larger yield. The soils are benefited by the applications of lime but are not markedly in need of this material. They are of a high quality, productive, and desirable.

DUFFIELD SOILS

The Duffield soils are found only in Franklin County and have been included on the map with the Hagerstown soils. They are derived from a mixture of weathered material, from interbedded limestones and shales, and generally have a brown surface with a yellow or reddish yellow subsoil. They occupy gently rolling uplands, are naturally well drained, and do not suffer from erosion. The silt



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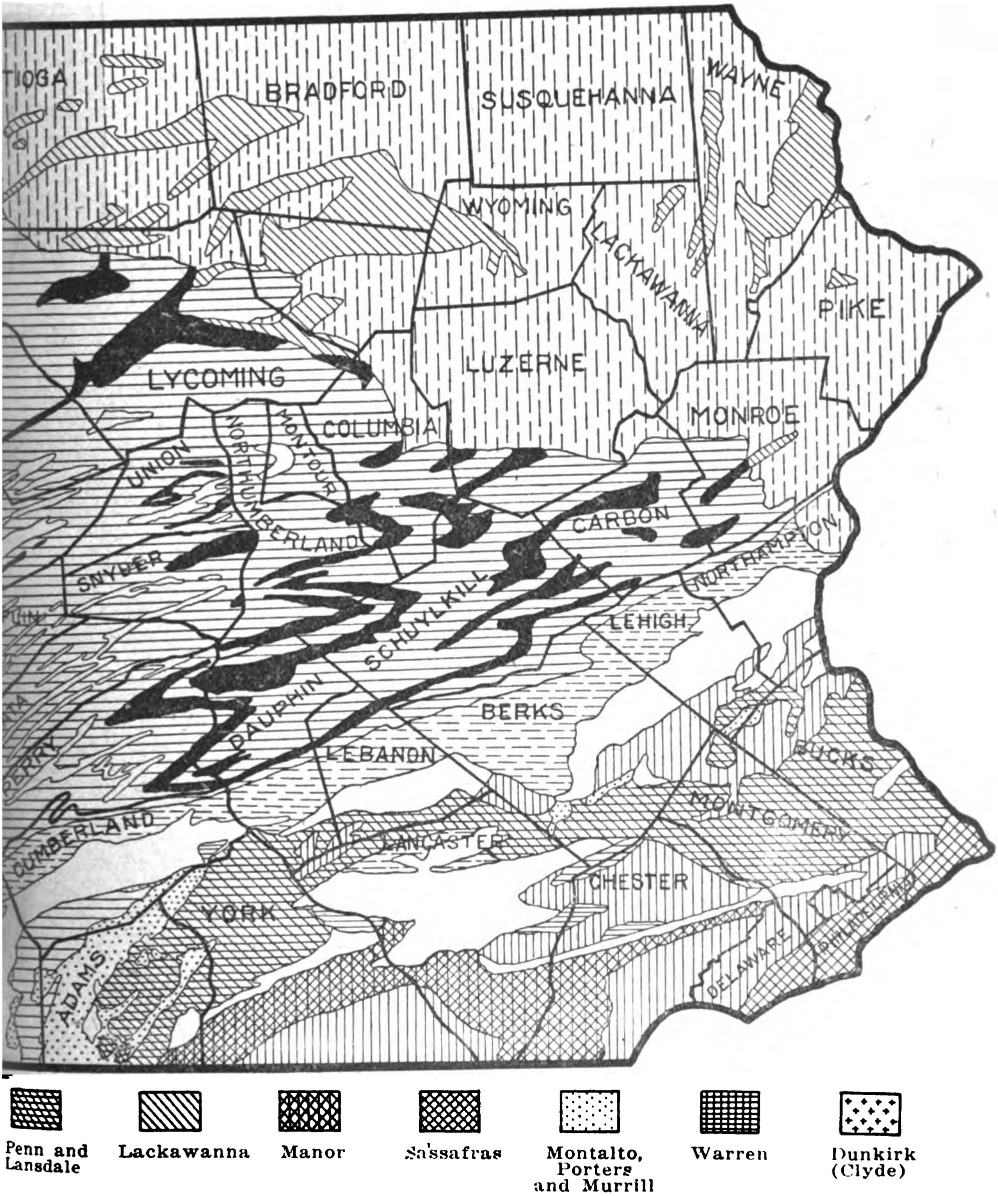

loam is the most extensive type. The soils are considered equal to the Hagerstown in productiveness, and being more easily tilled, are more desirable than those soils. They are adapted to the same crops as are the Hagerstown soils and are held at about the same value per acre.

FRANKSTOWN SOILS

The Frankstown soils are not shown on the map but are included with the Hagerstown soils. About one-third of the total area covered by the long, narrow strips of Hagerstown soils is composed of the Frankstown series.

These soils are derived from the weathering of rather impure cherty limestones and calcareous shales of the Lower Helderberg or associated formations. They have gray to grayish brown surface soils with yellow or yellowish gray subsoils. They occupy low steep-sided ridges, usually occurring on one side of the ridge, while the Hagerstown stony clay or clay occupies the top and opposite flank. In such positions the soil occurs in very narrow bands with steep slopes and is quite subject to severe erosion. The soils are occasionally found as rather large areas occupying rounded, low knobs or broadened ridges. Chestnut Ridge in Bedford County is the largest of these areas. Erosion, while active, is not so severe on the larger areas as on the narrow ridges. Drainage conditions are uniformly good on the Frankstown soils. The stony loam is practically the only type represented in the series. The surface is a fine silt loam but is obscured by the 50 to 70 per cent of small angular stone fragments present in the soil. The subsoil is even more stony than the surface and the "soil" mass is heavier, usually a silty clay loam.

The soils give good results when farmed to corn, grain or grass, and do fairly well for potatoes. They are primarily adapted to the production of apples, and extensive plantings of this fruit are being made, especially in Bedford County. Peaches are also well adapted to these soils and excellent yields of a high quality fruit are realized. Apples come into bearing early and yield good quantities of fruit of excellent quality. The coloring on red apples is especially fine and the Jonathan and Winesap varieties produce exceptionally fine fruit. The Frankstown soils, except where isolated from markets or shipping points, will become one of the leading series in the production of apples in this state.

BERKS SOILS

The Berks soils are formed by the weathering of thin-bedded shales, shaly sandstone, and slates. The soils are derived almost wholly from the formation known as the Utica and Hudson River slates and shales that lie above the Trenton limestones. The Berks soils are usually developed as a belt along one or both sides of the limestones valleys. In the section where the limestone valleys are borderd by the rather steep mountain slopes, the Berks soils are often obscured, being frequently covered by a considerable overburden of sandstone material carried down from the higher slopes.

Typically, the Berks soils have a yellowish brown to brown surface with yellow subsoils, although there are regions where the subsoil is somewhat grayish, and other places where both soil and subsoil have a reddish tinge. In the latter places the soils approach the Penn in color. The soils occupy a moderately hilly topography, existing as a series of low rounded hills and ridges with narrow steep-sided valleys, the whole region being one of quite varied but not extreme topographic relief. The soils are relatively shallow, generally resting on the unweathered shale at 3 feet or less. The rocks weather rather rapidly and where the soil is so shallow that the underlying shale is turned up by the plow the rock fragments will usually soften and break down to a soil in one or two seasons. Drainage is usually excessive although there are occasional places where seepage waters have accumulated and artificial drainage is necessary. Erosion is severe throughout the entire area of these soils, the shallow depth, light nature of the soil material, and steep position, all combining to make erosion most active and disastrous. The first effort of good farmers should be toward the control of soil washing, either by contour farming or, on the steeper slopes, by the construction of terraces. The soils are greatly benefited by the addition of organic matter, and marked increases in crops follow the application of barnyard manure or the plowing down of green material.

The soils occur in their largest body on the north side of the Great Valley between the foot of the mountains and the broad area of limestone soil, and extend in a continuous belt from the Delaware River across Northampton, Lehigh, Berks, Lebanon, Dauphin, Cumberland, and Franklin counties to the Maryland line. Another area of considerable extent lies in northern Lancaster County with smaller areas in Center and Mifflin counties. Throughout the series, the shale loam is the predominant type with the smaller areas of silt loam and loam and some occurrences of sandy and fine sandy loam. The soils are fairly well adapted to the production of potatoes, corn, wheat, and clover. Oats and buckwheat are also grown with considerable success. In Lehigh and Berks counties potatoes are a very important crop on these soils. Peaches and apples do quite well but there are few commercial plantings that have as yet come into bearing. The soils need thorough and careful tillage, with the view to the conservation of soil moisture and the prevention of erosion. They need regular applications of organic matter and, in most cases, give excellent response to applications of lime. The Berks soils are relatively easy to till and with care in handling can be made quite productive. They are usually valued at from one-half to two-thirds the price of adjacent limestone land while in productivity they will usually do from two-thirds to three-fourths as well as the limestone soils. Lighter teams can be used on the Berks soils and the wear and tear on tillage instruments is very much less. Owing to their steep position, it is more difficult to use the larger and heavier pieces of machinery.

DEKALB SOILS

The Dekalb soils have a gray to grayish brown surface soil with a yellow and sometimes mottled yellow and gray subsoils. The color varies somewhat, depending on the texture, the drainage, and the character of rock from which the soil is derived. The soils from the thin--bedded shales are usually lighter in color than those from the sandstones or the thick-bedded shales. In topographic position and general character, the soils of the eastern part of the State are different from those of the western portion. The Allegheny escarpment marks the boundary between the two divisions.

East of the Allegheny crest, the Dekalb soils are found on the narrow mountain ridges where they are derived mainly from hard sandstones (Madera-Oneida formations), and in long, ridged valleys where they are derived from thin-bedded platy shales (Chemung-Portage-Hamilton formations). In this section, but three types—rough, stony land, stony loam, and shale loam—are extensive. Some loam and silt loam are found on the lower slopes of the mountains, and some areas of sandy soils are found on the occasional flat spots on the mountain tops. Throughout this whole region, the topography is hilly to mountainous with a few areas of rolling to moderately hilly land where the shale valleys are broadest.

Erosion is very active over this whole region. On the mountain flanks the soil material is removed as fast as formed, leaving rough, stony land as the prevailing type. At the foot of the slopes where removal is not so rapid, the stony loam occurs, with small areas of loam, silt loam or even clay loam. In the shale valleys, erosive forces remove the soil material almost as fast as it is formed, leaving shallow soils full of shale fragments resting on the broken, slaty, shale rocks at a depth rarely exceeding three feet and often less than eighteen inches.

Drainage is good to excessive over all of the shale loam, is normally good on the sandy soils, but is often poor on the other types. The soils at the foot of the mountain slopes are often kept wet by waters that seep through the rough, stony lands of the mountain sides and in many cases artificial drainage is necessary in order to make these soils productive. In these wet areas the subsoil is often grayish or mottled.

West of the Allegheny escarpment the soils are derived from the hard Pocono sandstone and from the softer sandstones and thick shales of the Carboniferous formations. Viewed from an elevation, these soils appear to occupy a rolling plateau broken by a few low ridges. On closer inspection, the country is found to consist of an intricate network of narrow V-shaped valleys with rounded, steep-sided hills between. While erosion is quite severe over this area, the character of the rock is such that relatively deep soils are normally found. The Pocono formation gives rough, stony land with some areas of sandy soils, while the other rocks weather into a loam or silt loam, with large areas of stony loam and shale loam. The latter types are usually found on the steeper slopes where erosion is most active.

Throughout this plateau region, drainage is fairly good. On almost every farm there will be found some areas of relatively level land that is poorly drained, and more extensive areas along the foot of the hills where seepage from higher lying lands keeps the soils wet. Drainage of these areas is relatively easy and when supplied will work great improvements in the soils. The soils of the plateau region are quite productive, the loam and silt loam giving excellent results when farmed.

The Dekalb soils throughout the whole State are suited to the general farm crops, with dairying or stock raising as the leading farm industries. Grass grows well on all the types except the shallow phases of the shale loam. If well cared for, pastures can be maintained in a productive state for years, although short rotations are most desirable throughout the area. Wheat, rye, oats, and buckwheat are extensively grown. The latter crop reaches considerable importance in the counties on the Allegheny plateau. Corn is grown on the entire area of Dekalb soils, but the results average much below those from the Westmoreland or Hagerstown soils. A large amount of the Dekalb soil lies at such an elevation that the growing season is too short for the development and maturity of the grain. Ensilage corn can be successfully grown, however, and fits well into the scheme of operations on the dairy and stock farms. The shale loams east of the Allegheny escarpment are often too droughty to carry the corn crop to a satisfactory maturity. Potatoes are grown to some extent over the entire area covered by these soils but the returns are normally rather low. The crop is fairly well adapted to the better areas of loam and silt loam and could be made quite a profitable crop on these types. Near the larger towns, cabbage, tomatoes, and other truck crops are grown with excellent returns. Fruit is grown to some extent on the Dekalb soils and where properly cared for, good results are obtained. Apples do quite well on the well drained types and peaches have been found quite successful on the better drained areas of shale loam.

The Dekalb soils as a rule are deficient in organic matter and are almost invariably in need of lime. Farm practices on these soils should be so planned that it would be possible to work large quantities of barnyard manure or green cover crops into the soils at frequent intervals in the rotation. Throughout the entire region the tillage operations, especially plowing, are not sufficiently well done. The Dekalb soils should be plowed at least six inches deep and harrowing and cultivating should be sufficiently thorough to insure a fine seed-bed and maintain an efficient mulch. This is especially true on the lighter types where moisture conditions are normally unfavorable for the best growth of crops. With thorough tillage, together with applications of organic matter and lime, these soils can be put into excellent physical condition. Farm operations should be planned with a regular rotation of crops, a systematic application of lime, and a direct effort to reduce and control losses by erosion.

MORRISON SOILS

The Morrison soils are not shown separately on the map, being included with the Dekalb area. The soils have a yellowish surface with a yellowish to reddish subsoil. They are derived from sandstones and quartzites and occupy eroded ridges generally occurring in a limestone valley. They are most extensively developed in Center, Huntington, and Blair Counties. Drainage is excessive over most of the series, the soil and subsoil being so loose and porous that most of the water is readily lost by seepage. The soils have a low capillary power and crops suffer severely from drought. The soils are deficient in humus, of low productiveness, and are not farmed to any extent. They are locally known as "The Barrens" though they bear a fair stand of chestnut, oak and pine. The soils would be well adapted to truck and garden crops, to berries and to peaches if sufficient moisture could be supplied to carry the plants through the summer.

UPSHUR SOILS

The Upshur series of soils include those having a yellowish red to deep red surface with a yellowish red to an Indian red subsoil, derived from standstones and shales. In this state the soils are derived from the thin bedded sandstones of the Catskill formation, from the Chemung shale, and from the Mauch Chunk red shales. The areas derived from the latter formation generally occupy rather broad, irregularly-shaped valleys, with a rolling to hilly topography. The most extensive areas occur east of the Susquehanna River in the Lykens Valley, Cherry Valley, and Coyningham Valley. West of the river, the only large area of Upshur soils derived from Mauch Chunk shales is found in Trough Creek Valley and in Wells Valley. All of these sections have the typical rolling to somewhat hilly topography and generally have silt loam or loam soils. The other areas of Upshur soils occur as long narrow bands occupying a position on the flanks of the mountain ranges or on low ridges paralleling the mountains. These are nearly all derived from the Catskill rocks, and because of their steep position suffer very severely from erosion. The soil types found are usually shale loam with areas of stony loam and occasionally sandy loam. In some sections, notably in Cogan Valley, in Lycoming County, and in eastern Bedford and Fulton Counties, these hilly Upshur soils spread out and cover considerable area.

Drainage conditions are excessive on the shale loam and are good on practically all of the other types. Erosion is severe everywhere and its control is one of the most important factors in the proper management of the soils. The soils are uniformly deficient in organic matter and in most cases respond markedly to the application of lime. Proper tillage on the shallower soils will increase their depth and with care to prevent erosion will very materially increase their crop producing power.

In the more level valleys goods results are obtained with corn, wheat, potatoes, clover, and the grass crops. Buckwheat is grown to considerable extent and some fruit is being grown. On the hilly areas general farming is the rule, although the returns are relatively low. Where the soils have been improved by the addition of organic matter and lime, fair results are secured and in some cases good yields of potatoes, grain, and grass have been obtained. If the soil fertility is maintained, good results can be obtained from peaches and some varieties of apples.

WESTMORELAND SOILS

The Westmoreland soils have a grayish brown to a yellowish brown surface with a yellowish brown or yellow subsoil. The surface soil is normally mellow and rarely clods or bakes. The subsoil is usually much heavier than the surface. The soils are derived from interbedded sandstones and shales, together with layers of limestones and calcareous shales. The limestone is not sufficiently prominent to make the soil distinct from that rock but in almost every case limestone material enters into the make-up of the soil mass. The soils closely resemble the Dekalb, being distinguished from them by the browner color and the presence of the lime and the limestone fragments in the soil. If the amount of limestone material in the soil is large, the color usually becomes somewhat reddish, approaching the Brooke series in color and character.

The Westmoreland soils occur in the southwestern part of the State covering all of Green, Washington, and Allegheny Counties and parts of Butler, Beaver, Westmoreland, and Fayette Counties. with smaller areas in Indiana, Armstrong, and Lawrence Counties.

The soils occupy a rolling to hilly topography with some relatively level uplands but throughout most of the area level stretches are few, the elevated areas being rolling with many steep slopes. The region is cut through by the Allegheny, the Monongahela, and Youghiogheny rivers and their tributaries. Each of the larger streams has cut well down below the general level of the country and occupies a narrow canyon or V-shaped valley. The smaller tributaries generally have a steep gradient from their headwaters to their mouths and have cut narrow steep-sided valleys throughout most of their courses.

The soils, as a whole, are fairly well drained, although there are some small areas, usually on the lower slope where artificial drainage would be of material benefit. The soil suffers severely from erosion and gullies are frequent on the unprotected hill slopes. It is necessary to plow and plant on contours in order to prevent washing in the tilled fields, while on many of the steeper slopes, terracing is necessary to check the formation of these gulleys. On many of the steeper hill sides land-slips may occur. These are brought about by a thorough saturation of the soil mass, rendering it less cohesive and allowing the whole mass to break away and slip bodily down the hillside. These breaks usually occur across a slope and are caused by seepage water that comes to the surface along these lines. The slips tend to form a sort of natural terrace across the hillside but owing to the fact that they will be liable to move annually, they cannot safely be farmed. Occasionally these slips may extend as a narrow band from the top to the bottom of the hills, representing a line of seepage of water that accumulates on a more level upland. Though a striking feature of the landscape, these slips, in most cases, can be prevented by removing the seepage waters by properly located tile drains.

Five types of soil have been recognized, but of these the silt loam alone is extensive, the other types occupying relatively small areas. The silt loam is a rather deep mellow soil with a silty clay loam subsoil and is easily tilled and kept in good physical condition. As a whole, the soils are deficient in organic matter and are almost invariably in need of lime. Normal yields will range about 20 per cent above those from the Dekalb soils in similar condition. Corn, oats, wheat, buckwheat, and potatoes are the usual farm crops. Corn does very well and on the better farmed soils wheat is a profitable crop. The soils are primarily adapted to the production of grass and are well suited for a dairying or stock raising industry. In the past, cattle and sheep raising was a very important part of the agricultural activities of the region. Economic conditions have caused the stock industry to decline and at the present time large areas of soil, that were formerly used as pasture, are devoted to the production of a very inferior class of hay. In many cases the meadows are mowed annually for from five to twenty years and the land grows up to weeds and short-stemmed grasses of little value.

Fruit does fairly well on the Westmoreland soils, peaches proving rather more satisfactory in most cases than apples. It is quite probable that with varieties suited to the climate and soil conditions, apples could be made a very successful crop. Bush fruits do well and truck and garden crops are successful on the lighter type.

The Westmoreland soils in the past have been held in very high regard, and there is no reason, if given good tillage and supplied with organic matter and lime, why they should not again become one of the leading series of soils in the western part of the State. One of the crying needs of these soils is a re-arrangement of the leasing system, enabling the tenants to feel assured of their occupancy of the land for a considerable length of time.

BROOKE SOILS

The Brooke soils are of little extent in the State, being found in small irregular patches usually occupying hilltops in the area generally covered by the Westmoreland series. They are derived from limestone and are found where the layers of limestone occur as the surface rock on hilltops or where the thicker layers outcrop along the slope. The soils have a brown to reddish brown surface with a reddish brown to deep red subsoil. The clay and clay loam are the most common types and usually are fairly well drained. The soils are well adapted to general farm crops of the region giving yields that will range from 15 to 25 per cent higher than those on the Westmoreland soils. The Brooke soils are not shown on the map but are included with the Westmoreland.

VOLUSIA SOILS

The Volusia soils have a gray to grayish brown surface with a yellowish or mottled subsoil. Where the drainage is good the subsoils are generally some shade of yellow but if the drainage is poor, the subsoils vary from gray to drab with many bodies marked by a mottling with spots of red, gray, and yellow. The subsoil is generally heavy, frequently a silty clay or clay that is quite impervious to water. The soil mass is normally three feet or less in depth resting on broken shale or sandstone. The soils are derived from a mixture of glacial till and decomposed material from the underlying shale and sandstone. In most cases, the glacial material represents but a small part of the soil mass, the larger portion being derived from the native rocks.

The soils occupy a hilly region with a somewhat subdued topography. The Volusia soils in the western part of the State occur on broadly rolling plateaus with steep slopes to the streams which are normally considerably below the general level of the plateau. Toward the east the soils become rougher, with a hilly to almost mountainous topography. In the northeastern part of the State these soils occupy a hilly topography, the whole county consisting of a succession of smooth contoured hills and rather narrow, steep-sided valleys. In parts of Tioga, Lycoming, and Wyoming Counties, and in Sullivan, Luzerne, Carbon and Monroe Counties, the topography in places is mountainous, the glacial action having little effect in smoothing the contours of the hard sandstone mountains. Here the glaciation has had little effect on the soils, the stony loam and rough stony land predominating, yet everywhere one finds evidence of till deposits, and on the flatter mountain tops some areas of good farm lands, mainly of till or morainic material, are found. The changed character of the soil is strikingly shown in the forest cover. On the non-glacial areas, of Dekalb or Upshur, the rough mountains are covered with a growth of chestnut and oak with some pines and hardwoods. On the Volusia mountainous areas, maples, beeches, and oaks are the leading trees, with some hemlocks, hickories, birches, etc. The changed forest is apparent as soon as the terminal moraine is crossed even though there seems to be but little difference in the superficial appearance of the soil. The fine glacial till, though a small part of the soil mass, has the deciding influence on the character of the natural growth. This seems to be mainly due to its effect in retarding the natural drainage.

The Volusia soils, as a whole, have poor drainage. From one-half to two-thirds of the whole area must be supplied with artificial means of removing the water before the land will produce to its full capacity. In many cases, however, the productive power of the soil would be too low to warrant the expense of installing a system of tile drains. When first cleared, the soils contained large amounts of organic matter and were fairly well drained through openings made by the roots growing through the clays into the open rock below. The tillage methods that have been practiced have served to deplete the organic matter, and with the decay of the tree roots, the openings that had been made were closed up and drainage retarded or stopped. In some sections it is said that the "climate has changed" but, as a matter of fact, the shorter growing season is due to the undrained condition of the soil, making need for an extra two or more weeks of warm sunny weather in order to permit drying out enough for the soil to be plowed and seeded. Artificial means of draining will add from two weeks to a month to the growing season on most of the Volusia soils.

Erosion is severe over all of the hillier sections, washes and gullies being common on all the slopes. Better drainage, permitting more of the water to go through the soil instead of over it, will reduce erosion somewhat but preventive methods such as contour plowing, leaving strips of sod across the slopes, or even terracing, must be practiced in order to prevent the severe losses due to this action.

The silt loam and the shale loam are the most extensive types in this series. The stony loam is quite extensive, while the clay, clay loam, and sandy members are relatively unimportant. The sandy and gravelly soils are rarely found except on the morainic deposits.

The soils are primarily adapted to grass, while potatoes, oats, buckwheat, and rye are important crops. Fruit does well on the well drained soils, some varieties of apples dong especially well. Dairying is the leading farm industry throughout the entire Volusia region. In the northwestern part of the State, creameries and cheese factories are numerous and the major part of dairy products are marketed as butter or cheese. In the eastern area, a large amount of whole milk is shipped to Philadelphia and New York. This is produced along the trunk lines of railways crossing the area, the milk being shipped on express trains once or twice each day. In the region more distant from the shipping point, creameries handle the milk supply, marketing the product in the form of butter or occasionally as cream. The dairying industry depends to a large extent on summer pasture and, although the land is well adapted to grass, poor methods of handling are giving rather poor pasture. The applications of manures or fertilizers to the pasture lands will increase the yields and prolong the life of the pastures. Better pasturage can also be obtained by shortening the rotation period and not leaving the land in grass for so long a period of time. Corn, when grown for ensilage, gives good results but much of the area has too short a season for the development and maturity of the grain. If the soils are well drained so that they can be worked early in the spring, both the dent and flint corns can be brought to maturity without difficulty. Corn yields are fairly good.

On the loam and better drained areas of the heavier soils, late potatoes are a successful crop. With proper methods of culture, yields from 150 to 200 bushels per acre can be obtained without difficulty. Wherever the marketing conditions justify, the area of potatoes can well be extended. Oats and rye are the leading grain crops on the Volusia soils. Wheat is not grown to any great extent in the northeast counties and the area in the western counties is smaller than that devoted to rye. The latter crop is grown extensively with fairly good returns. It seems to stand the poor drainage and the severe winters rather better than wheat and is generally used as a nurse crop for clover and timothy. The crop is important, although the yield is rather low. It is sometimes used as a nurse crop for the grasses. Buckwheat is grown extensively in both sections, although it does not occupy a definite place in the rotation scheme. It is planted on new ground and on the meadowland that has been plowed up for the first time after a long period of years. It is also planted whenever, through late season or excessive rains, one of the other crops proves a failure. The yields of this crop vary greatly, depending on the time of sowing and the preparation of the ground. In most seasons, the early sowed buckwheat gives the best results although quite often the later crops give a good yield. Apples are being produced on a commercial scale in some of the eastern counties. They do quite well giving good quality of fruit and a fairly good yield. The Northern Spy and Rhode Island Greening seem to be very well adapted to the heavier type, while the Baldwin seems to give the best results in the lighter and better drained soils.

The Volusia soils are markedly in need of lime. They uniformly give an "acid" reaction and striking increases in crop yields are obtained by the application of lime. The use of this material, together with better drainage, will increase crop yields from 25 per cent to 75 per cent on most of the farm lands. Lime, drainage, organic matter, and better tillage are all needed on these soils.

Agricultural conditions on the Volusia soils are rather poor. The rural population in most of the counties where these soils occur has been decreasing steadily during the last thirty years, and with this change in population has come a decrease in the crop yields and in the value of the land. At the present time, in many sections, farms can be bought for a price lower than the cost necessary to replace the buildings. Land values will range from $15 to $40 per acre with an average price in the neighborhood of $25. The future of the Volusia soils depends on the development of the dairy industry and the availability of the supply of lime. The soils are not inherently poor, and if properly handled would give good returns on the capitalization of from $50 to $100 per acre.

THE DUTCHESS SOILS

The Dutchess soils have a brown to light brown surface with a yellowish brown to reddish brown subsoil. They are derived from the glaciation of the Utica and Hudson River slate and shales, and resemble the Berks soils in many ways. Just one area, lying in the eastern part of Northampton County, has been encountered. The soils are prevailingly loam and shale loam and are devoted to the general farm crops with considerable areas in potatoes. They occupy a rolling to hilly topography with some rather smooth or undulating areas. The soils are not shown on the map but are included with the Volusia. In crop-producing power and in value, they are estimated to be slightly higher than the Berks series. The stony loam type is rarely as good as the other soils, often being too rough and stony for agricultural purposes.

THE WARREN SOILS

The Warren series occur in a narrow strip in Warren and Crawford Counties, between the Dekalb and Volusia soils, and are quite similar to the Dekalb in character and appearance. They have been derived to a large extent from the weathering of shales and thin-bedded sandstones with an admixture of a small amount of glacial material. The soils have a grayish color with a light gray to dark gray subsoil. They are generally more than three feet in depth and are fairly well drained. They are superior to either the Volusia or Dekalb soil in crop production but are of limited extent and only locally important. The crop adaptation is similar to that of the Delkab silt loam and loam.

THE LACKAWANNA SOILS

The Lackawanna soils have a red to yellowish red surface with a deep red or yellowish red subsoil. They are derived from the feeble glaciation of red sandstones and shales and are made up of the mixture of material transported some distance by the glacier together with material that has been weathered from the underlying local rocks. The soils are very similar to the Volusia, except in color. They occupy about the same topographic position, occurring on hilltops, slopes, or in rolling to hilly areas. The soils are rather better drained than the Volusia but otherwise have the same needs—organic matter, lime and tillage. The soils are found only in the northeastern part of the State, the larger areas lying in Bradford and Sullivan Counties. The soils are being farmed to the same crops as are grown on the Volusia soils, with yields varying but little from those obtained on the Volusia.

The shale loam is the most extensive type, with smaller areas of loam and silt loam. Some other minor types also occur. The soils relatively shallow, the shale loam being but a few inches thick, resting on broken, partially weathered shale rock. The soil is rather droughty and for the ordinary farm crops, careful methods of tillage are necessary in order to get good results. These soils seem to be fairly well adapted to the production of apples and in some cases, some rather extensive commercial orchards are to be found.

DUNKIRK SOILS

The Dunkirk soils have a characteristic brown or grayish brown or grayish surface with a yellow to brown subsoil mottled where the drainage conditions are poor. The soils are derived from the weathering of glacial lake deposits and occur as a series of sloping terraces lying along Lake Erie in a belt varying from two to six miles in width. East of Erie the soils occupy three or more well defined terraces rising in steps of from twenty to fifty feet from the Lake to the ridge on the south. West of Erie the terraces are not so well defined and, in the vicinity of Conneaut, the Dunkirk soils occupy a single, sloping terrace, ranging in elevation from fifty to about one hundred feet above the present level of the lake. The eastern portion of the soils have fairly good drainage, with a gravelly loam and sandy loam as the predominant type. In the western section the drainage is much poorer and the heavy soils are more extensive. The well drained soils are well adapted to the production of fruit and are especially well adapted to grapes, large areas being devoted to the production of Concord and other varieties grown for table use or to be manufactured into grape juice or wine. Grape growing is the most important industry on the Dunkirk soils and incidentally this is the only soil in the State where grapes are extensively produced. On the better drained soils, peaches, apples, and bush fruits are extensively grown and the production of vegetables and truck crops is an important industry near the larger towns and shipping points. On the heavier soils, potatoes, corn, wheat, oats, clover, and other forage crops, including alfalfa, are successfully grown. Some of the poorest-drained areas of silty clay loam and silty clay, seem to be worthless for agricultural purposes unless a very thorough system of drainage is installed. It is a question whether these soils would warrant the expense necessary for such drainage.

The needs of the Dunkirk soils vary rather widely. On the heavier members, drainage and lime are the first needs while on the lighter types, the incorporation of organic matter is most urgent. Thorough methods of tillage are necessary on all types in order to get the best returns.

CLYDE SOILS

There are a few areas of Clyde soils included with the Dunkirk series. The Clyde have dark brown to black surface with dark gray or mottled subsoil. They have been formed by the weathering and reworking of glacial lake deposits under poor drainage conditions with the resulting accumulation of large quantities of organic matter. The soils generally have a poor drainage, but when drainage is supplied, give excellent yields of onions, cabbage, celery, and similar crops. The soils are of little extent in the State and have not been differentiated on the map.

RIVER BOTTOM AND TERRACE SOILS

Along nearly all the streams in the State, there occur narrow strips of soil composed of material that has been transported and deposited by the action of the stream. A part of these soils lie immediately along the stream banks and are subject to annual or, at least periodic, overflow. These soils are known as the River Bottom Lands and vary quite widely in color, origin, and in texture. The soils have been grouped in the four main series, the Genesee and Barbour occurring within the glaciated area, while the Huntington and Moshannan occupy most of the river bottoms in the balance of the State.

The Genesee soils have yellow to brown color and are derived from the reworking and deposition of the glacial material. They represent, to a large extent, material washed from the Volusia hillsides. The Barbour soils have a red color and represent the material eroded from red sandstones and shales together with the glacial material of the Lackawanna series.

The Huntington soils have a brown to light brown color and represent a mixture of transported material derived from sandstones and shales with occasionally some limestone fragments. They are extensively developed in the State and are found along nearly all the streams outside of the glaciated region. The Moshannan soils have a deep red color and to a large extent are composed of the wash from the Upshur series. They are relatively inextensive in this State.

The Terrace soils lie above present overflow and represent the deposits of the stream at earlier times when the volume of water carried was greater than at present or when the stream had not cut its bed down to the present position. The soils are generally sandy to gravelly in character and have been grouped in the three main series. All of these have a light brown to yellowish color and their separation has been based largely on the origin of the material from which they are derived. The Chenango soils are made up almost wholly of material that has been transported by glacial action, and represent high terraces deposited by the glacial flood waters. The Wheeling soils represent a mixture of material from the glacial and residual region, while the Holston soils are made up wholly of material derived from the residual upland. The Chenango and Wheeling soils are quite similar in character, their main difference being evidenced in the layer of coarse gravel that is uniformerly found beneath the Chenango. This is usually absent from the Wheeling soil section. The Holston soils are darker in color than the other terrace areas and are generally free from gravel deposits in the deeper subsoil.

These bottom and terrace soils are generally very productive and, wherever they occur in an extensive area, are highly developed. They are adapted to truck and garden crops, to corn, potatoes, and other general farm crops, and to alfalfa and other hay crops. The soils, wherever they occur in large areas, are uniformly well drained and easily tilled. Unfortunately, the major portion of these soils occurs as narrow strips along the streams; the terraces often excessively drained and the bottoms with poor drainage. Where the soils are found in broad areas, as at the junction of two streams, they are usually occupied by a town and their higher value as sites for towns, factories, and railway yards. For this reason, these rich, alluvial soils are of little importance in a consideration of the agriculture of the State.

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The Pennsylvania State College
Agricultural Experiment Station

BULLETIN No. 133

STEER FEEDING EXPERIMENTS

STATE COLLEGE
CENTRE COUNTY, PENNSYLVANIA
NOVEMBER, 1914.

THE PENNSYLVANIA STATE COLLEGE

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BULLETIN No. 133

STEER FEEDING EXPERIMENTS

By W. H. TOMHAVE AND C. W. HICKMAN.

CONCLUSIONS.

1. Corn silage at $3.50 per ton is slightly more economical when used as the sole roughage for steers, than a combination of mixed hay and silage in which the silage is limited to 20 pounds per had daily when hay, costing $12.00 per ton, is freely fed.

2. A ration of mixed hay and corn stover as roughage, with broken ear corn, or corn and cob meal, and bran as grain, when fed throughout the entire feeding period, is not economical in Pennsylvania. The cattle fed this ration through the entire feeding period produced 100 pounds of gain at an average cost of $12.97, while those receiving no grain during the first 56 days except cottonseed meal, and what grain was present in the silage, made 100 pounds of gain at an average cost of $10.48. Wheat bran as a source of protein at $25.00 per ton is much more expensive than cottonseed meal at $34.00 per ton. The additional cost of grinding corn is not repaid by greater gains from steers.

3. Alfalfa hay at $15.00 per ton, when fed at the rate of 5 pounds per 1000 pounds live weight in combination with corn silage, is not so efficient as a source of protein as 2½ pounds of cottonseed meal per 1000 pounds live weight daily at $34.00 per ton. The feeding of 5 pounds of alfalfa hay with 2½ pounds of cottonseed meal per 1000 pounds live weight daily as a source of protein, in a ration of corn silage and corn, is not now economical. Alfalfa hay, fed in combination with corn silage during the first 56 days with corn added to the ration for the balance of the period, reduced the cost of gains, but also decreased the rate of gain, as compared with the ration differing by the addition of cottonseed meal.

4. Corn silage at $3.50 per ton as the sole roughage is more economical than corn silage and alfalfa hay combined, when alfalfa hay costs $15.00 per ton.

5. The cost of producing a pound of gain was considerably less during the first period, when roughage only was fed, than during the second period, when grain also was fed.

6. Cattle receiving no corn silage, but fed corn from the beginning of the experiment, consumed more dry matter daily than those fed corn silage without corn.

INTRODUCTION.

The prevailing high price of beef cattle during 1911, 1912, and 1913 created unusual interest in this class of live stock in Pennsylvania. Feeding cattle were in strong demand in the fall of 1913 and consequently sold at extremely high prices. The prevailing price was about one dollar per hundred higher than during the same time the previous year. As compared with conditions existing during 1912 and 1913, the price of all farm feeds ranged much higher. The high prices paid for feeders combined with high priced grain and roughage made cattle feeding an unprofitable enterprise during the past winter. Very few cattle feeders realized financial profit after allowing prevailing market prices for roughage and grain fed.

The unfavorable market conditions for finished cattle during the spring of 1914 materially reduced the returns from cattle in the feed lots of Pennsylvania. As a consequence of these conditions the financial results obtained during the past year are not normal. While the financial returns show a deficit this year, it must be remembered that last year the profits from cattle feeding were considerably greater than the losses this year. It should also be noted that in the experiment of this year a higher price has been allowed for the farm feeds than a year ago.

Objects.

The objects of this experiment were: **First,** to secure more information concerning the value of corn silage as a roughage for fattening cattle; **Second,** to determine the difference in the cost of feeding cattle by the common Pennsylvania method and that adopted by the Experiment Station; **Third,** to determine the value of alfalfa, as a source of protein, in a ration for fattening cattle, as compared with cottonseed meal; **Fourth,** to determine whether a ration containing alfalfa hay requires additional protein from some concentrated feed such as cottonseed meal; **Fifth,** to compare rations in which the roughage is composed of corn silage only, corn silage and mixed hay, and corn silage and alfalfa hay; **Sixth,** to determine the cost of producing a pound of gain during the first part of the feeding period, when roughage alone is fed, as compared with the latter part of the feeding period, when grain is added to the ration.

Description of Cattle.

The cattle used in this experiment were of mixed breeding, with beef blood predominating. They were purchased in Roane County, West Virginia, and would have classed as 'fair feeders' on the Pittsburgh market. They were two-year-olds, averaging a little more than nine hundred pounds each at the beginning of the experiment. The sixty head purchased were divided into five lots of twelve head each, as equally as possible according to age, type, breed, weight, quality, and general condition. The average individual weight at the beginning of the experiment of the lightest lot was 910 pounds, while those in the heaviest lot averaged 926 pounds.

Shelter, Feed Lots, and Water Supply.

The cattle were fed in sheds enclosed on three sides and open to the south. The covered part of the sheds for each lot was 14 x 30 feet which provides ample protection from rain, snow, and sleet, except during severe storms from the south. A pen 25 x 30 feet joined each shed so as to permit the cattle to exercise in the open. The uncovered portions of the feed lot had concrete floors which kept the cattle free from mud in rainy weather, and retained all fertility until it was hauled away. A large amount of bedding was required to absorb the accumulation of water during wet weather, but the amount of manure produced increased in proportion.

Open galvanized tanks filled with water were constantly kept before the cattle. During cold weather the ice was broken twice daily to allow the cattle to drink.

The Rations.

The steers in Lot I received the ration which is commonly fed in Pennsylvania. It was composed of mixed hay and corn stover as roughage, and chopped ear corn, or corn and cob meal, and bran as concentrates. The steers received all the mixed hay they would consume and four pounds of corn stover per head daily in addition.

The grain mixture was composed of three parts corn and one part bran. Of this the animals were fed twice daily all they would readily consume (while the mixed hay was fed in the evening and the corn stover in the morning).

Lot II received corn silage as the sole roughage during the entire feeding period. During the first 56 days no grain was added to the ration except cottonseed meal, which was fed at the rate of 2½ pounds per 1000 pounds live weight daily and continued throughout the entire feeding period. At the close of the 56-day feeding period, ear corn was fed at the rate of 15 pounds per 1000 pounds live weight daily for which 12 pounds of shelled corn was substituted later.

Lot III received corn silage and alfalfa as roughage during the entire feeding period. The alfalfa was fed to supply the required protein in the ration. This lot received no grain during the first 56 days of the feeding period. The alfalfa was fed at the rate of 5 pounds per 1000 pounds live weight daily and the corn silage according to appetite. At the end of the 56-day feeding period, ear corn was added to the ration at the rate of 15 pounds per 1000 pounds live weight daily for which 12 pounds of shelled corn was substituted later.

Lot IV received corn silage and mixed hay as roughage, corn silage being fed at the rate of 20 pounds per head daily and the mixed hay ad libitum. The roughage, with cottonseed meal at the rate of 2½ pounds per 1000 pounds live weight, was fed daily during the first 56 days. Ear corn was added to the ration for the balance of the feeding period, at the rate of 15 pounds per 1000 pounds live weight daily. During the latter part of the feeding period, the ear corn was replaced by shelled corn which was fed at the rate of 12 pounds per 1000 pounds live weight.

Lot V received corn silage and alfalfa hay as roughage. The alfalfa hay was fed daily at the rate of five pounds per 1000 pounds live weight. In addition to this the steers received all the corn silage they would consume. This roughage, in combination with 2½ pounds of cottonseed meal per 1000 pounds live weight, was fed during the first 56 days of the feeding period. Ear corn at the rate of 15 pounds per 1000 pounds live weight was fed daily for two months, while for the balance of the feeding period the grain ration was changed to 12 pounds of shelled corn.

Manner of Feeding.

The time of feeding was the same for all lots. The cattle of all lots were fed at 6 A. M. and 4:30 P. M. daily.

Lot I received grain and corn stover in the morning and grain and mixed hay in the evening.

Lot II was fed corn silage both morning and evening with the allowance of cottonseed meal poured over it. During the second period, in which the cattle received both grain and silage, the grain was fed first, after which the silage was put in the manger.

Lot III was fed its allowance of alfalfa hay which was followed by silage at both feeding times. When grain was given, it was fed before the roughage.

Lot IV received hay in the morning and corn silage in the evening. The cottonseed meal was poured over the silage in the evening. During the second part of the feeding period the roughage was fed in the same order.

Lot V received silage both morning and evening. The cottonseed meal was poured over the silage at each feeding. The allowance of alfalfa hay was fed immediately before the silage was consumed both morning and evening. When corn was added it was fed before the roughage.

Quality of Feeds.

The quality of the feed used in this test was good. The silage, was made from corn bordering on maturity, some of which was frosted, and was put up in a wooden stave silo. The silage kept in good condition with the exception of slight freezing during the winter. The mixed hay, grown on the college farm, was of high quality. The alfalfa was produced on the college farm and was cured in splendid condition. Most of the ear corn fed was purchased in the vicinity of the Experiment Station. It was well matured and of good quality. All the shelled corn used was purchased on the Buffalo market and was graded No. 3 Yellow Dent. The cottonsed meal was a standard 41 per cent protein product. The bran was spring wheat bran purchased from a western mill.

Prices of Feeds.

The prices of feeds used in the financial statement are based upon the prices which prevail in the vicinity of State College dur-

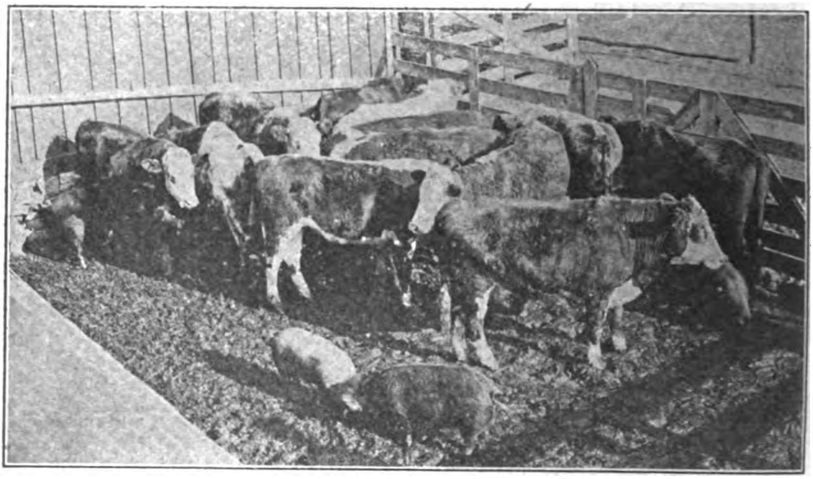

Fig. 1.—Lot I at Beginning of Experiment.

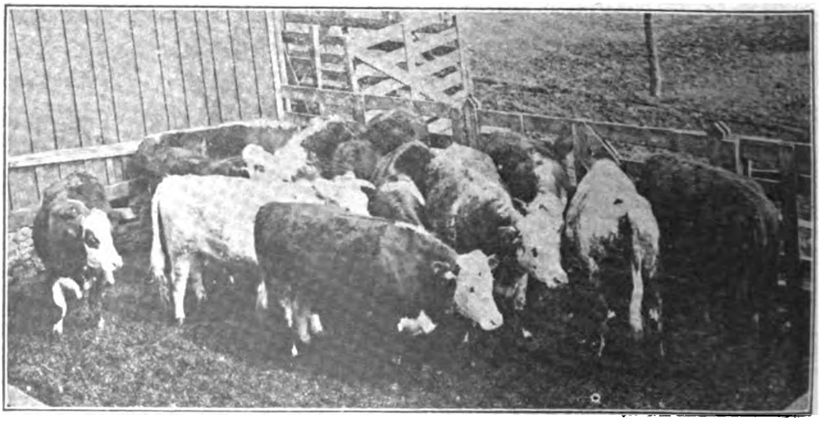

Fig. 2.—Lot I at Close of Experiment.

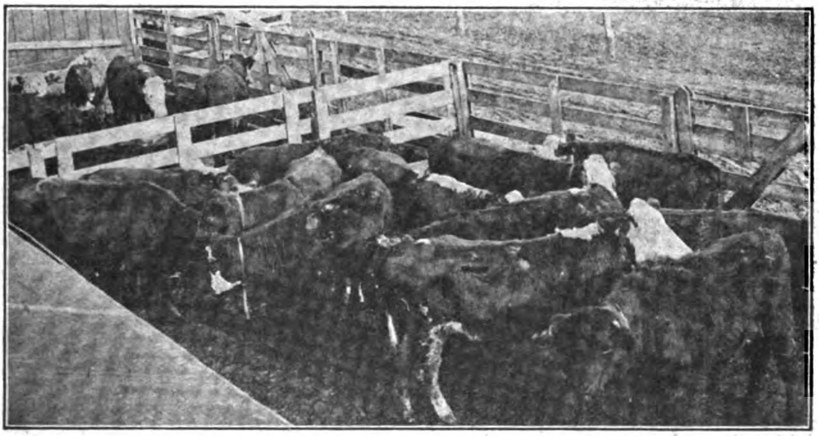

Fig. 3.—Lot II at Beginning of Experiment.

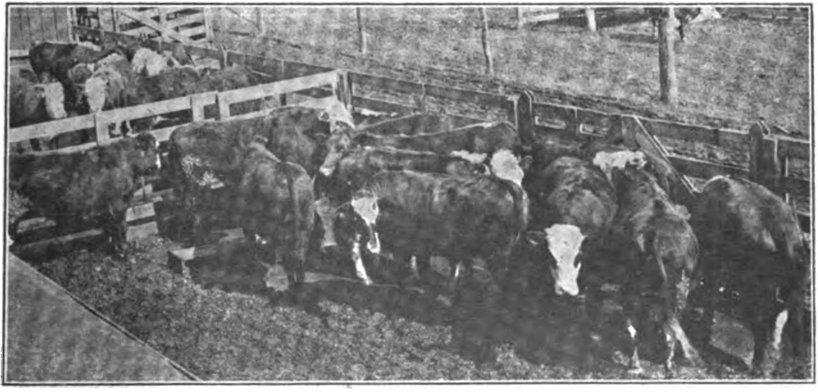

Fig. 4.—Lot II at Close of Experiment.

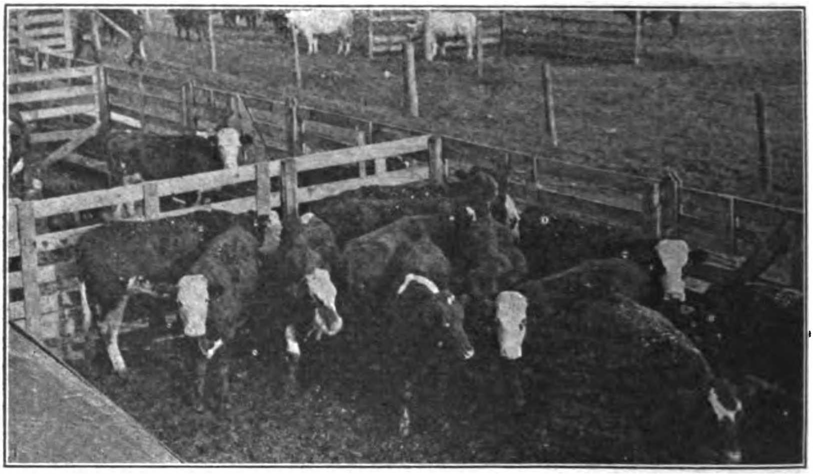

Fig. 5.—Lot III at Beginning of Experiment.

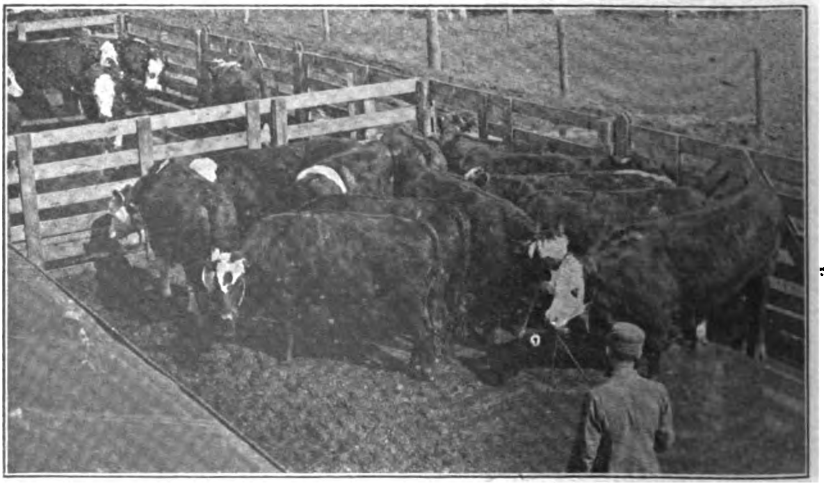

Fig. 6.—Lot III at Close of Experiment.

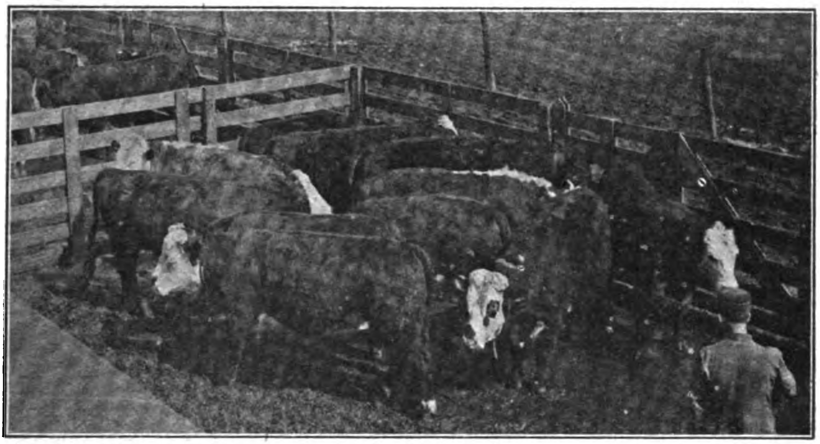

Fig. 7.—Lot IV at Beginning of Experiment.

Close

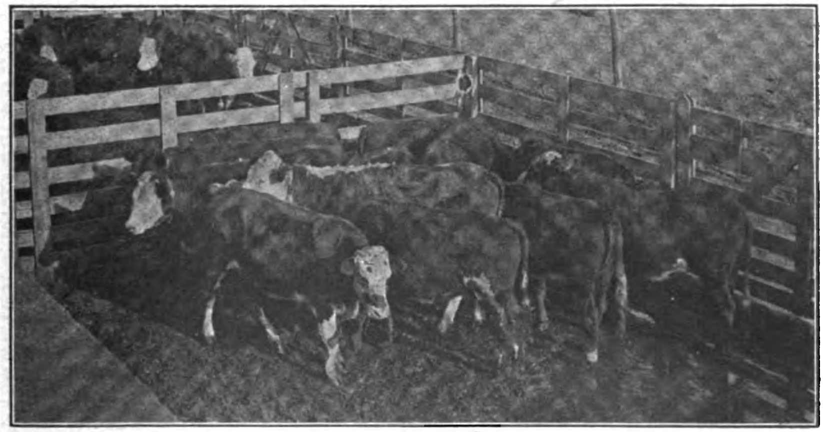

Fig. 8.—Lot IV at Close of Experiment.

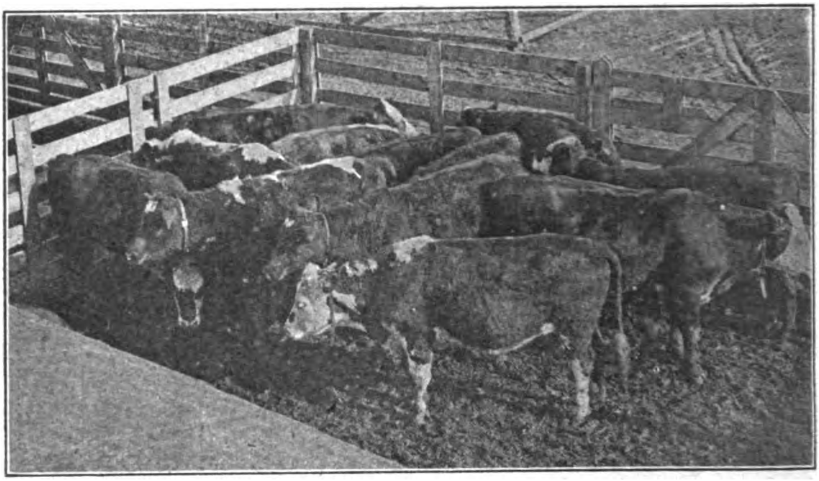

Fig. 9.—Lot V at Beginning of Experiment.

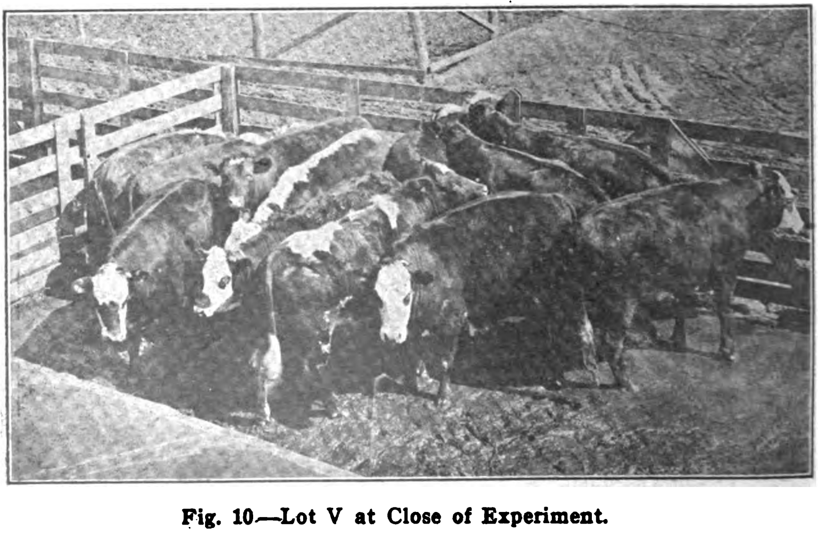

Fig. 10.—Lot V at Close of Experiment.

ing the winter. Corn silage was valued at $3.50 per ton, mixed hay $12.00 per ton, ear corn 70 cents per bushel of 70 pounds, shelled corn 70 cents per bushel of 56 pounds, corn and cob meal at 75 cents per bushel of 70 pounds, bran $25.00 per ton, cottonseed meal $34.00 per ton, alfalfa hay $15.00 per ton, and corn stover $3.50 per ton.

Weights and Weighing.

Each steer was weighed individually for three consecutive days at the beginning of the feeding trial, at the end of 56 days, and at the close of the experiment. At the end of every four weeks, individual weights were taken one day and group weights were taken the previous and following days. Group weights were taken also in the middle of each four-week period. The weighing was done each time at 9 A. M. without any change in the feeding and handling of the cattle.

Hogs in the Feed Lot.

Hogs were put in each lot at the beginning of the experiment. The average weight of the pigs put on the experiment at the beginning was 114.5 pounds. Six were placed in Lot I, four in Lots II and III, and three in Lots IV and V. The number was increased to six and seven for each lot when corn was added to the ration. Owing to the absence of grain from the ration during the first part of the feeding period, corn and tankage were fed to the hogs in addition to the droppings from the cattle. When grain was added to the ration, light fall pigs weighing 55 pounds were placed in Lots IV and V.

TABLE I.—Air-Dry Moisture in Feeds*.

	Nov. 28	Jan. 7	Feb. 4	Mar. 4	Apr. 1	Average amt. of air dry matter in feeds
Ear corn	18.60	17.74	17.74	18.60	.....	81.830
Wheat bran	14.93	14.05	16.31	10.26	13.49	86.195
Corn stover	2.88	5.54	26.79	36.63	19.72	81.688
Mixed hay	11.32	24.42	23.17	9.85	17.56	82.736
Corn silage	63.73	72.18	70.28	68.42	77.05	29.668
Cottonseed meal	7.19	7.69	17.74	8.33	13.12	89.186
Alfalfa hay	15.63	23.47	12.59	8.91	15.63	84.754
Shelled corn	.....	.....	.....	.....	10.85	89.150
Corn & cob meal	.....	.....	14.18	14.00	14.11	85.003

*Reported by the Department of Experimental Agricultural Chemistry.

Samples of feed were taken each month to the laboratory of Experimental Agricultural Chemistry for air-dry moisture determinations. In making a study of Table I, it will be noted that the amount of moisture in the ear corn did not vary much during the entire feeding period. Wheat bran varied slightly, being highest in moisture content during February and lowest during March. Corn stover varied more than any of the other feeds. The stover was very dry during the fall and early winter. During February, March, and April it was fed as taken from the field which accounts for the high moisture content. The cottonseed meal was fairly uniform in moisture content except during the months of February and April. Mixed hay varied from 9.85% for March to 24.42% for January. Corn silage was quite uniform, however, increasing slightly in moisture content during the winter. This was possibly due to the fact that the corn in the top of the silo was a little more mature and consequently contained less moisture. The alfalfa hay varied from 8.91 per cent in March to 23.47 per cent in January. Shelled corn contained only 10.85 per cent moisture, being of good No. 3 grade. The corn and cob meal was very uniform and varied little during the three months in which samples were taken.

By a study of Table II, which shows the amount of feed offered and refused, it will be noted that Lot I received all the roughage they would consume. They refused more corn stover than any other feed, owing to the liberal feeding of other roughage. The amount of corn stover consumed decreased as the feeding period progressed. The amount of hay consumed varied little during the entire feeding period. That they were receiving all they would consume is indicated by the fact that they refused a small amount each two-week period. They refused a small amount of bran also during the first two months, being unaccustomed to full grain feeding. They refused none of the corn or corn and cob meal during the entire feeding trial.

A study of Lot II indicates that the cattle in that lot received all the corn silage they would consume as roughage. The amount was gradually increased during the first 56 days. As soon as ear corn was added to the ration, the corn silage consumption decreased. This decrease continued, so that at the end of the feeding period the steers were consuming less than half the amount consumed at the end of the first 56 days. None of the cottonseed meal was refused; and only a small amount of the ear corn, when it was first fed.

Lot III refused a small amount of corn silage and alfalfa. Most of this was refused when grain was first added to the ration. The amount of alfalfa hay fed and consumed was increased as the weight of the cattle increased. It became necessary to reduce the amount of silage after grain was added to the ration, and less than one-half the amount consumed at the beginning of the test was fed at the close of the test. A small amount of ear corn was refused shortly after corn was first added to the ration. The shelled corn was all consumed during the time it was fed.

The steers in Lot IV, which received mixed hay and corn silage as roughage, were fed all the hay they would consume, and in addition 20 pounds of silage daily. The amount of corn silage offered remained constant throughout the entire experiment. The amount of hay consumed gradually decreased after the grain was added to the ration so that at the end of the feeding period the steers were receiving less than one-half the amount of hay consumed at the beginning of the test. Practically all the ear or shelled corn fed was consumed except during the last two weeks when ear corn was fed, at which time a small amount was refused.

Lot V received all the roughage they would consume in the form of silage and alfalfa hay. The amount of corn silage fed was gradually increased from the beginning of the experiment until grain was added to the ration, after which it was gradually decreased. The amount of alfalfa hay was gradually increased throughout the entire experiment. The cattle refused some of the alfalfa hay at every period of the experiment, the amount refused being largest at the end of the eight-week period when the grain was added. The allowance of alfalfa hay was more readily consumed when the allowance of silage was decreased. The ear corn fed was readily consumed during the entire period except during the month of February, when 211 pounds were refused, the bulk of which was the cobs from which the corn had been shelled.

It is difficult to make a comparison of the amounts of roughage consumed by the several lots, owing to the differences

TABLE II.—Feeds Offered and Refused. (Pounds)

Lot I.—12 Steers.

Date 1913—1914	Offered					Refused		
	Corn stover	Mixed hay	Wheat bran	Ear corn	Corn and cob meal	Corn stover	Mixed hay	Wheat bran
Nov. 12—26	700	1584	888.5	1165.5	.....	181	20	15
Nov. 26—Dec. 10	745	1680	565.5	1606.5	.....	275	42.5	13
Dec. 10—24	673	1680	619.5	1858.5	.....	256	29	8
Dec. 24—Jan. 7	672	1680	651.0	1953.0	.....	209	52	18
Jan. 7—21	476	1680	651.0	......	1953	344	61.5	0
Jan. 21—Feb. 4	448	1680	672.0	......	2016	171	72.5	..
Feb. 4—18	652	1680	672.0	......	2016	280	87.0	..
Feb. 18—Mar. 4	392	1680	689.0	......	2004	240	59.0	..
Mar. 4—Mar. 18	392	1680	700.	......	2100	201	33.0	..
Mar. 18—Apr. 1	392	1680	728.	......	2184	107	33	..
Total	5542	16704	6345.5	6673.5	12363	2363	489.5	49

Lot II.—12 Steers.

Date 1913—1914	Offered				Refused		
	Corn silage	Cottonseed meal	Ear corn	Shelled corn	Corn silage	Ear corn	Shelled corn
Nov. 12—26	6625	332	....	....	111	.....	..
Nov. 26—Dec. 10	8300	392	....	....	73	.....	..
Dec. 10—24	8400	406	....	....	44.5	.....	..
Dec. 24—Jan. 7	8850	420	....	....	84.75	.....	..
Jan. 7—21	6850	420	1554	....	230.75	....	..
Jan. 21—Feb. 4	3850	448	2172	....	283.5	125.	..
Feb. 4—18	4900	462	2232	....	20.0	120.5	..
Feb. 18—Mar. 4	4900	470	2346	....	51	182.5	..
Mar. 4—18	4250	476	....	1030	6	.....	8
Mar. 18—Apr. 1	4200	490	....	2100	.....	.....	..
Total	63125	4322	8304	4030	854.5	328.0	8

Lot III.—12 Steers.

Date 1913—1914	Offered				Refused			
	Corn silage	Alfalfa hay	Ear corn	Shelled corn	Corn silage	Alfalfa hay	Ear corn	Shelled corn
Nov. 12—26	6150	770	....	....	222.0	8.0	...	....
Nov. 26—Dec. 10	6900	798	....	....	42.0	16.0	..	....
Dec. 10—24	7000	798	....	....	80.5	31.0	...	....
Dec. 24—Jan. 7	7450	952	....	....	48.5	10.25	...	....

Jan. 7—21	5850	840	1554	....	108.25	102.00	...	....
Jan. 21—Feb. 4	4700	882	2172	....	126.00	209.0	...	....
Feb. 4—18	4200	910	2282	....	45.5	85.	62	....
Feb. 18—Mar. 4	4200	924	2346	....	83.0	78.	182	....
Mar. 4—18	3550	952	....	1980	10.	14.	...	4
Mar. 18—Apr. 1	2800	952	....	2100	......	......	...	....
Total	52800	8778	8304	4030	654.75	564.75	194	4

Lot IV.—12 Steers.

Date 1913—1914	Offered					Refused			
	Corn silage	Mixed hay	Cottonseed meal	Ear corn	Shelled corn	Corn silage	Mixed hay	Ear corn	Shelled corn
Nov. 12—26	3180	1584	332	....	....	166.	73.	.....	..
Nov. 26—Dec. 10	3360	1680	392	....	....	4.	44.5	.....	..
Dec. 10—24	3360	1760	390	....	....	0.	86.	.....	..
Dec. 24—Jan. 7	3360	1820	420	....	....	5.	47.25	.....	..
Jan. 7—21	3360	1380	420	1554	....	46.5	194.75	18.	..
Jan. 21—Feb. 4	3360	1140	434	2172	....	79.0	251.0	11.	..
Feb. 4—18	3360	960	455	2232	....	81.0	197.0	74.5	..
Feb, 18—Mar 4	3360	840	476	2346	....	41.	151.	112.5	..
Mar. 4—18	3360	840	476	....	1930	0.	42.5	.....	5
Mar. 18—Apr. 1	3360	840	490	....	2100	.....	57.5	.....	..
Total	33420	12844	4294	8304	4030	372.5	1094.5	216.0	5

Lot V.—12 Steers.

Date 1913—1914	Offered					Refused			
	Corn silage	Alfalfa hay	Cottonseed meal	Ear corn	Shelled corn	Corn silage	Alfalfa hay	Ear corn	Shelled corn
Nov. 12—26	5900	688	332	....	....	124.5	17.5	.....	..
Nov. 26—Dec. 10	6550	798	392	....	....	38.5	74.5	.....	..
Dec. 10—24	6300	798	392	....	....	46.5	75.0	.....	..
Dec. 24—Jan. 7	6750	840	420	....	....	82.75	24.0	.....	..
Jan. 7—21	5050	840	420	1554	....	81.5	154.0	5.	..
Jan. 21—Feb. 4	4400	868	434	2172	....	122.0	205.0	16.	..
Feb. 4—18	3500	896	448	2232	..	53.0	124.0	60.5	..
Feb. 18—Mar. 4	3500	924	462	2346	..	44.0	105.0	150.5	..
Mar. 4—18	3500	952	476	....	1930	13.0	27.5	.....	18
Mar. 18—Apr. 1	2800	966	476	....	2100	......	12.5	.....	..
Total	48250	8570	4252	8304	4030	555.75	819	232.	18

in the combinations fed. The amount of cottonseed meal varied little for the three lots receiving it as a source of protein. The amount of ear and shelled corn varied but little for Lots II, III, IV, and V. Lot I consumed considerably more grain than any other lot, as it received grain from the beginning of the feeding trial.

Table III is presented to show the average amount of feed consumed daily by each steer by twenty-eight day periods. Each lot of cattle was started on feed gradually and brought to a full feed as rapidly as possible. Lot I was started on 4 pounds corn stover per head daily, the amount being increased until at the end of ten days they were receiving five pounds per head daily, which is the maximum amount received at any time. Mixed hay was fed at the rate of 8 pounds per head daily at the beginning and gradually increased to ten pounds per head daily. The grain mixture of three parts corn and one part bran was fed at the rate of 6 pounds per head daily at the beginning and gradually increased until at the end of two weeks the cattle were receiving 12½ pounds per head daily. This amount was increased as rapidly as they would consume it. The average amount of corn stover consumed per head daily was greatest during the first four weeks. It was gradually decreased each period except the fourth when a little more was consumed than during the preceding four weeks. The amount of mixed hay consumed per head daily varied little. The maximum amount was 9.81 pounds per head daily, the minimum 9.57 pounds per head, or an average for the entire feeding experiment of 9.67 pounds per head daily. The grain consumed was gradually increased during each period, 11.34 pounds being fed during the beginning period and 16.31 pounds during the final period, or an average of 15.08 pounds per head daily for the entire feeding period.

At the beginning of the experiment Lot II was fed daily 33.3 pounds of corn silage per head. This amount was increased to 37.5 pounds after the third day and to 50 pounds at the end of the 16th day. For a short time during the second period, this lot received 54 pounds per head daily. The cottonseed meal was gradually increased from one pound per 1000 pounds live weight at the beginning of the test until at the end of the first week they were receiving daily their allowance of 2½ pounds of cottonseed meal per 1000

TABLE III.—Showing Average Amount of Feed Consumed Daily per Head by Steers, November 12, 1913, to April 1, 1914, (28-Day Periods) 140 Days.

	Lot I Lbs.	Lot II Lbs.	Lot III Lbs.	Lot IV Lbs.	Lot V Lbs.
First Period.					
Corn stover	2.94	......	......	......	......
Corn silage..............	......	43.87	38.053	18.958	36.568
Mixed hay	9.59	......	......	9.36	......
Alfalfa hay	......	......	4.61	......	4.15
Ear corn	8.52	......	......	......	......
Wheat bran	2.82	......	......	......	......
Cottonseed meal	......	2.155	......	2.155	2.155
Air-dry matter	20.586	17.912	17.878	17.180	18.763
Second Period.					
Corn stover	2.62	......	......	......	......
Corn silage	......	51.10	42.785	19.985	38.60
Mixed hay	9.81	......	......	10.412	......
Alfalfa hay	......	......	5.085	......	4.58
Ear corn	11.35	......	......	......	......
Wheat bran	3.72	......	......	......	......
Cottonseed meal	......	2.46	......	2.437	2.416
Air-dry matter	22.332	16.486	15.794	15.675	16.475
Third Period.					
Corn stover	1.22	......	......	......	......
Corn silage	......	37.80	30.719	19.63	27.52
Mixed hay	9.60	......	......	6.17	......
Alfalfa hay	......	......	4.256	......	4.01
Ear corn	......	11.089	11.089	11.003	11.026
Corn and cob meal......	12.00	......	......	......	......
Wheat bran	3.93	......	......	......	......
Cottonseed meal	......	2.59	......	2.54	2.54
Air-dry matter	21.733	21.964	21.867	21.718	22.849
Fourth Period.					
Corn stover	1.53	......	......	......	......
Corn silage	......	28.96	27.74	19.786	17.866
Mixed hay	9.57	......	......	4.32	......
Alfalfa hay	......	......	4.988	......	4.735
Ear corn	......	12.72	13.047	13.068	12.997
Corn and cob meal......	12.23	......	......	......	......
Wheat bran	4.08	......	......	......	......
Cottonseed meal	......	2.79	......	2.77	2.708
Air-dry matter	23.770	22.060	22.985	23.024	24.870
Fifth Period.					
Corn stover	1.17	......	......	......	......
Corn silage	......	25.125	18.27	20.00	18.71
Mixed hay	9.80	......	......	4.70	......
Alfalfa hay	......	......	5.625	......	5.589
Shelled corn	......	11.985	11.982	11.975	11.94
Corn and cob meal......	12.75	......	......	......	......
Wheat bran	4.25	......	......	......	......
Cottonseed meal	......	2.875	......	2.875	2.833
Air-dry matter	23.632	18.950	19.758	21.644	19.758
Average for 140 days.					
Corn stover	1.89	......	......	......	......
Corn silage	......	37.07	31.04	19.67	28.33
Mixed hay	9.67	......	......	6.99	......
Alfalfa hay	......	......	4.83	......	4.61
Ear corn	3.97	4.75	4.83	4.84	4.80
Shelled corn	......	2.40	2.40	2.40	2.39
Corn and cob meal......	7.36	......	......	......	......
Wheat bran	3.76	......	......	......	......
Cottonseed meal	......	2.57	......	2.56	2.53
Air-dry matter	22.410	19.074	19.656	19.848	21.006

pounds live weight. The amount of corn silage consumed daily was materially reduced as soon as ear corn was added. The average amount consumed daily during the first two periods was 47.48 pounds, while during the time grain was fed the amount consumed was 30.63 pounds per head. The cattle were started on six pounds of ear corn per head, which amount was increased daily until the full allowance was fed at the end of two weeks. The average daily amount of grain consumed per head in Lot II was 9.72 pounds as compared to 15.08 in Lot I to which grain was fed from the beginning.

Lot III consumed an average of 40.419 pounds of corn silage during the first two months, or "roughage feeding period." They received daily 33.3 pounds per head at the beginning of the trial, the amount being gradually increased as rapidly as they would consume it. The maximum amount consumed at any time by this lot during the second period was 42.75 pounds. The amount of silage was greatly reduced toward the end of the experiment, which was necessary so that the cattle would consume the allowance of alfalfa hay and grain. The average daily consumption of silage for the last three months was 25.576, or 17.18 pounds less than when no grain was added to the ration. The alfalfa, used as a source of protein, was fed daily at the rate of 3.75 pounds per head at the beginning and gradually increased to the full allowance of 5 pounds per 1000 pounds live weight. This lot of cattle consumed daily an average of 12.04 pounds of ear or shelled corn per head during the time that grain was fed.

Lot IV consumed an average of 19.67 pounds of corn silage throughout the entire experiment. This was nearly their full allowance of 20 pounds per head daily. They consumed daily an average of 6.99 pounds of mixed hay per head for the entire feeding period. During the first 56 days or, "roughage feeding period," they consumed daily 9.88 pounds of hay per head which amount was greatly reduced as soon as grain was added to the ration. The full allowance of cottonseed meal was consumed as fed throughout the entire experiment. The grain allowance averaged 12.03 pounds per head daily for the third and fourth months while ear corn was fed. An average of 11.975 pounds of shelled corn was consumed during the last month of the experiment.

Lot V consumed an average of 28.33 pounds of corn silage for the entire period. During the first 56 days when no grain was fed they averaged 37.584 pounds daily. This amount was greatly reduced as soon as grain was added to the ration, averaging 21.36 pounds per head daily during the grain feeding period. This reduction in the amount of silage fed was necessary to induce the cattle to consume their allowance of alfalfa hay and grain. The quantity of alfalfa hay consumed varied little during the test, but increased gradually with the increase in weight of the cattle. The full allowance of 2½ pounds of cottonseed meal per 1000 pounds live weight was consumed daily. An average of 12 pounds of ear corn was consumed during the two months in which it was fed, and 11.94 pounds of shelled corn was consumed daily during the last month.

The amount of air-dry matter consumed by four-week periods is quite uniform in Lots II to V, inclusive, for both the first and second four-week periods. Lot I, receiving grain in the ration, but no silage, consumed 20.586 pounds of dry matter daily, as compared with 17.912 pounds of air-dry matter for Lot II, which received corn silage only as roughage. The average amount of air-dry matter for the four lots, receiving no grain except cottonseed meal and silage as all or part of the roughage, is 17.933 pounds for the first four weeks, as compared with 20.586 pounds per head daily for the lot receiving grain and no succulent feed. The same general relation continued during the second four-week period, except that the amount consumed by Lot I was greater than in the preceding four weeks and lower in the other lots. Lots II to V, inclusive, averaged 16.107 pounds per head daily as compared with 22.332 pounds per head daily for Lot I. During the third and fourth four-week periods there was very little difference in the five lots. A further marked difference was noted in the fifth or last four-week period. Lot I continued to consume 22.410 pounds per head daily, while the other lots dropped to an average of 20.025 pounds per head daily which was due to a more concentrated grain in the form of shelled corn. The average amount of air-dry matter consumed for the entire 140 days was highest in Lot I and lowest in Lot II which was due entirely to the character of the ration fed.

TABLE IV.—Average Daily Gain per Steer by Periods.

Period.	Lot I		Lot II		Lot III		Lot IV		Lot V	
Nov. 12—26	1.567	1.53	1.885	1.50	1.498	1.22	.635	1.498	2.38	1.617
Nov. 26—Dec. 10	1.488		1.121		.942		2.361		.853	
Dec. 10—24	3.393	1.895	3.403	2.24	3.998	1.77	3.055	1.746	2.48	1.696
Dec. 24—Jan. 7	.396		1.091		-.456		.436		.912	
Jan. 7—21	1.537	1.899	2.622	2.21	2.866	2.177	2.212	2.29	2.301	2.13
Jan. 21—Feb. 4	2.26		1.795		1.488		2.361		1.954	
Feb. 4—18	2.470	1.51	2.343	1.608	2.500	1.85	3.055	1.746	3.075	1.76
Feb. 18—Mar. 4	.556		.874		1.20		.436		.446	
Mar. 4—18	2.302	1.662	1.508	1.612	1.329	1.354	2.034	2.103	2.024	2.019
Mar. 18—April 1	1.022		1.716		1.379		2.173		2.014	
Nov. 12—Jan. 7, 56 days		1.71		1.875		1.495		1.622		1.656
Jan. 7—April 1, 84 days		1.691		1.809		1.799		2.045		1.969
Nov. 12—April 1, 140 days		1.699		1.83		1.674		1.87		1.844

Table IV gives the average daily gain per head by two-week periods. It will be noted that the gains made by all lots during the first six weeks were satisfactory. Lot I made an average daily gain of 2.149 pounds: Lot II, 2.136 pounds; Lot III, 2.146 pounds; Lot IV, 2.017 pounds; and Lot V, 1.904 pounds. The gains made during the seventh and eighth weeks were unsatisfactory and greatly reduced the average for the first 56-day period.

This factor is in keeping with results obtained at this station in previous experiments, namely, that the cattle fed a large amount of roughage during the early part of the feeding period seemed to cease making substantial gains at the end of the sixth week. It will be noted, however, that the cattle in Lot I also made very poor gains during the same period, even though fed a liberal amount of grain. Weather conditions or some other factor common to all lots may have been the cause of this reduction in gains. As soon as grain was added to the ration of the lots receiving roughage only, the rate of gain increased and so continued until the period from February 18 to March 4, during which time a severe snowstorm made all cattle in the lots somewhat uncomfortable just prior to weighing, and possibly caused the poor gains for the two-week period. The average daily gains for the first and second periods were more uniform in Lots I and II than in the other three lots. Both of these lots possibly received a greater amount of grain owing to the grain fed Lot I and the full feed of silage for Lot II.

The gains for Lots III, IV and V were higher during the second period than during the first period. The average for the entire period was lowest in Lots I and III, while Lots II, IV and V were quite uniform. The smaller gains made in Lot I were no doubt due to the absence of silage in the ration, while that of Lot III is due to the small amount of grain or concentrated feed consumed because of the absence of the cottonseed meal. The average daily gains made by all lots except Lot I were all that could be expected from the character of the rations fed. The sudden falling off in gains at the end of the sixth week would seem to indicate that a two-month roughage feeding period is too long.

TABLE V.—Showing Amount of Feed and Dry Matter Consumed Daily per Steer by Periods, Amount of Air-Dry Matter per Pound of Gain, and Cost of Producing a Pound of Gain.

First Period (56 days)	Lot I	Lot II	Lot III	Lot IV	Lot V
Corn stover	2.78 Lbs.	.....	.....	......	......
Mixed hay	9.70 "	.....	.....	9.886 Lbs.	......
Wheat bran	3.27 "	.....	.....	...... "	......
Ear corn	9.935 "	.....	.....	...... "	......
Corn silage	..... "	47.485 Lbs.	40.419 Lbs.	19.47 "	37.584 Lbs.
Alfalfa hay	..... "	..... "	4.847 "	...... "	4.365 "
Cottonseed meal	..... "	2.307 "	..... "	2.296 "	2.285 "
Air-dry matter	21.482 "	17.352 "	16.852 "	16.498 "	17.671 "
Average daily gain..............	1.711 "	1.875 "	1.495 "	1.622 "	1.656 "
Air-dry matter per pound of gain	12.553 "	9.254 "	11.268 "	10.165 "	10.606 "
Cost per pound of gain.........	11.80c	6.524c	7.161c	8.164c	8.291c
Daily cost of feed..............	20.090c	12.231c	10.709c	13.243c	13.736c
Second Period (84 days)					
Corn stover	1.307 Lbs.	.....	..... "	......	...... "
Mixed hay	9.657 "	.....	..... "	5.064 Lbs.	...... "
Alfalfa hay	..... "	.....	4.956 Lbs.	...... "	4.778 Lbs.
Corn silage	..... "	30.628 Lbs.	25.576 "	19.805 "	21.365 "
Wheat bran	4.087 "	..... "	...... "	...... "	...... "
Cottonseed meal	..... "	2.75 "	...... "	2.728 "	2.694 "
Ear corn	..... "	11.905 "	12.068 "	12.036 "	12.012 "
Shelled corn	..... "	11.985 "	11.982 "	11.975 "	11.94 "
Corn and cob meal.............	12.327 "	..... "	...... "	...... "	...... "
Air-dry matter	22.936 "	20.883 "	21.412 "	22.269 "	22.882 "
Average daily gain.............	1.691 "	1.809 "	1.790 "	2.046 "	1.907 "
Air-dry matter per pound of gain	13.211 "	11.534 "	11.935 "	10.888 "	11.620 "
Cost per pound of gain.........	13.79c	12.62c	11.174c	11.81c	12.717c
Daily cost of feed..............	23.33c	22.85c	21.00c	24.16c	25.04c
Average daily gain (140) days...	1.699 Lbs.	1.83 Lbs.	1.674 Lbs.	1.87 Lbs.	1.844 Lbs.
Air-Dry matter per pound gain (140 days)	13.103 "	10.516 "	11.534 "	10.649 "	11.197 "
Cost per pound gain (140 days).	12.97c	10.131c	10.104c	10.55c	11.124c
Daily cost of feed (140 days)...	22.043c	18.604c	16.92c	19.79c	20.52c

Table V is presented to show the average amount of feed consumed daily per steer during each feeding period. It also shows the amount of air-dry matter consumed daily per steer, the average daily gain per steer, the air-dry matter required to make one pound of gain, the cost per pound of gain, and the daily cost of feed for each steer at the prices charged. During the first period, Lot I consumed the greatest amount of air-dry matter per head daily, requiring 21.482 pounds. For Lot II, there were required 17.352 pounds; for Lot III, 16.852 pounds; for Lot IV, 16.498 pounds; and for Lot V, 17.671 pounds. Lot I, receiving no silage in the ration, consumed 4.98 pounds more air-dry matter per day than the lowest lot receiving silage.

The air-dry matter required to make a pound of gain was also greatest in Lot I. It required 12.553 pounds to produce a pound of gain for Lot I, as compared with 9.254 pounds for Lot II; 11.268 pounds for Lot III; 10.165 pounds for Lot IV; and 10.666 pounds for Lot V. This would seem to indicate that the ration fed Lot I for the first period was not as efficient as the rations of the silage-fed lots. This conclusion is in keeping with previous experiments which show that silage added to the ration will render the feeds more digestible. The greater amount of air-dry matter consumed daily by Lot I is also due to the more concentrated grain feed which was not used for the other four lots.

A marked difference in the lots is noted for the first period when the feed cost of producing one pound of gain and the daily cost of feed are compared. The cost of producing a pound of gain in Lot I is 11.8 cents, as compared with 6.524 cents for Lot II, in which the cheapest gains were made. The second highest cost is 8.91 cents for Lot V, for which both alfalfa hay and cottonseed meal formed a part of the ration. The daily cost of feed per steer per day was also greatest in Lot I, being 20.19 cents; Lot II, 12.23 cents; Lot III, 10.70 cents; Lot IV, 13.24 cents; and Lot V, 13.73 cents per day.

The feeding of expensive grains and no silage in Lot I made the daily cost of feed very much higher than that of any of the other lots. It also showed that a ration of corn stover, mixed hay, corn, and wheat bran is inefficient, as compared with a ration made up largely of roughage during the early feeding period in which silage is the main roughage. The daily cost of feed was lowest in Lot III where corn silage and alfalfa hay alone were fed. The daily gains made by this lot were not sufficient to indicate it as the lot in which a pound of gain was produced at the lowest cost. Lot II, fed corn silage and cottonseed meal, produced the cheapest gain. The addition of mixed hay in Lot IV increased the daily cost of feed as well as the cost of a pound of gain. This is also true of Lot V, where cottonseed meal was fed in addition to the silage and alfalfa hay. This would indicate that it is not advisable to feed both cottonseed meal and alfalfa hay in the amount fed in addition to corn silage as a source of protein. It also indicates that mixed hay at $12.00 per ton is more expensive as a roughage than corn silage at $3.50.

Observations were made of the condition of the cattle at the end of the 56-day feeding period. The cattle in Lot II had the sleekest coats, but the cattle in Lot I seemed to be a little thicker-fleshed than those of the other lots. This condition was doubtless due to the feeding of grain from the beginning.

During the second period when grain was fed to all lots there was very little difference in the amount of air-dry matter consumed by the five lots. Lot I again consumed the largest and Lot II the smallest amount. The amount of air-dry matter consumed daily was also slightly increased over the first period, due to the addition of a concentrated feed. The amount of air-dry matter required to make a pound of gain was also more uniform for the five lots. Lot I required 13.21 pounds of air-dry matter, the largest amount, while Lot IV required the lowest amount, 10.88 pounds.

The feed-cost of producing one hundred pounds of gain materially increased in all lots for the second period, except Lot I, as a result of adding grain to the ration at the beginning of that period. The increased cost of producing 100 pounds of gain during the second period was $1.99 for Lot I; $6.078 for Lot II; $4.01 for Lot III; $3.646 for Lot IV; and $4.426 for Lot V.

The daily cost of feed per steer was also increased for all lots during the second period. The daily cost was highest in Lot V, where grain was fed in addition to the corn silage, alfalfa hay, and cottonseed meal. The amount of roughage consumed by all lots was considerably less during the second period, due to the addition of grain, which also accounts for the marked increase in the cost per pound of gain and the daily cost of feeding.

Summarizing the results of both periods, we find that the average amount of air-dry matter required to make a pound of gain is quite uniform, except in Lot I, which required 13.10 pounds; Lot II required 10.516 pounds; Lot III, 11.534 pounds; Lot IV, 10.649 pounds; and Lot V, 11.197 pounds. The cost of producing a pound of gain is very uniform for the silage-fed lots, especially Lots II, III, and IV. The production of a pound of gain in Lot V. to which the greatest amount of protein was fed, became more expensive than where a smaller amount was consumed. In this regard, Lot I, which received grain from the beginning, and which was fed bran as a source of protein, was the most expensive. The cost of producing 100 pounds of gain for the entire period in Lot I was $2.87 greater per hundred compared with the cheapest of the other lots, and $1.85 higher than the most expensive lot where silage formed a part of the ration. The daily cost of feed per head for the entire period ranges from 22.04 cents for Lot I to 16.92 for Lot II.

Valuation of Cattle.

At the close of the experiment, Mr. J. Frank Woods, of the Pittsburgh Union Stock Yards, placed a value upon each lot of cattle, based upon the Pittsburgh market. He valued Lot IV at $8.40 per cwt., Lot II at $8.30, Lot I at $8.30, Lot V at $8.25, and Lot III at $8.15. In commenting on these cattle he stated that Lot IV carried the most finish and that they were in the highest condition. There was no difference between Lots I and II. The cattle in Lot I were a little thicker in flesh, while those of Lot II seemed to be a little sleeker, which would rate them at the same value on the market. Lot V was not as uniformly finished, while Lot III lacked thickness. It costs about 35 cents per hundred to ship cattle to the Pittsburgh market from State College. This amount allows for shrinkage, feed, freight, commission, etc. The entire lot of cattle was sold in the feed lot, after the close of the experiment, to Altoona (Pennsylvania) butchers at $8.20 per cwt. A shrinkage of 3 per cent was allowed, the cattle being weighed on full feed and water.

A review of the summary table indicates that every lot of cattle was fed at a financial loss. The steers were purchased as feeders on a high market and sold on a badly demoralized market. The initial cost of the cattle was $7.45. after all expenses in con-

TABLE VI.—Summary of Feeding Experiment.

	Lot I 12 steers	Lot II 12 steers	Lot III 12 steers	Lot IV 12 steers	Lot V 12 steers
Initial value per cwt	$7.45	$7.45	$7.45	$7.45	$7.45
Initial weight (lbs.)	10916.67	11003.33	11118.33	11033.33	10959.99
Final weight (lbs.)	13771.68	14088.35	13931.67	14185.00	14058.34
Total gain (lbs.)	2855.01	3085.02	2813.34	3151.67	3098.35
Average daily gain (lbs.)	1.699	1.83	1.674	1.87	1.844
Feed consumed—lbs.					
Corn stover	3179.	....	....	....	....
Mixed hay	16214.5	....	....	11749.5	....
Alfalfa hay	....	....	8213.75	....	7751.
Corn silage	....	62270.5	42145.25	83047.5	47694.25
Wheat bran	6296.5	....	....	....	....
Cottonseed meal	....	4322.	....	4294.	4252.
Ear corn	6673.5	7976.	8110.	8088.	8072.
Shelled corn	....	4027.	4026.	4025.	4012.
Corn and cob meal	12363.	....	....	....	....
Average daily feed per steer—lbs.					
Corn stover	1.89	....	....	....	....
Mixed hay	9.67	....	....	6.99	....
Alfalfa hay	....	....	4.83	....	4.61
Corn silage	....	37.07	31.04	19.07	28.38
Wheat bran	3.75	....	....	....	....
Cottonseed meal	....	2.57	....	2.56	2.53
Ear corn	3.97	4.75	4.83	4.81	4.80
Shelled corn	....	2.40	2.40	2.40	2.39
Corn and cob meal	7.36	....	....	....	....
Cost of feed per lot.					
Corn stover	$3.972	....	....	....	....
Mixed hay	97.287	....	....	$70.497	....
Alfalfa hay	....	....	$61.603	....	$58.132
Corn silage	....	$108.973	91.254	57.833	83.405
Wheat bran	78.706	....	....	....	....
Cottonseed meal	....	73.474	....	72.998	72.284
Ear corn	66.725	70.76	81.10	80.88	80.72
Shelled corn	....	50.338	50.324	50.313	50.149
Corn and cob meal	123.63	....	....	....	....
Cost of feed	370.331	312.55	284.28	332.52	344.75
Cost of gain per cwt.	12.97	10.13	10.104	10.55	11.12
Necessary selling value per cwt.	8.594	8.03	7.97	8.130	8.261
Actual selling price in lots	8.30	8.30	8.15	8.40	8.25
Initial value per steer	67.774	68.312	69.062	68.499	68.043
Selling value per steer	91.237	93.335	90.555	95.158	92.55
Cost of feed per steer	30.86	26.045	23.69	27.71	28.73
Loss per steer	7.34	1.022	2.161	1.05	4.220
Price received for a bushel of corn after paying for other feeds	.878c	.680c	.562c	.683c	.420c

nection with shipping them from West Virginia, and for hay and pasture which they consumed after reaching the Experiment Station were paid. The total cost of feed for the various lots is as follows: $284.28 for Lot III, $312.50 for Lot II, $332.52 for Lot IV, $344.75 for Lot V, and $370.33 for Lot I. The lower cost of total feed for any lot does not necessarily mean that it was the most economical. The value of the cattle at the close of the experiment may, in the case of a more expensive lot, be higher than a cheaply produced lot, as this test shows for Lot IV.

At the prevailing price of feeds, the margin necessary to break even on the cattle in the lots is as follows: Lot I, $1.14; Lot II, 58 cents; Lot III, 52 cents; Lot IV 69 cents; and Lot V, 81 cents. If the additional cost of 35 cents per cwt, required to get the cattle on the Pittsburgh market is added to the margin necessary in the feed lot, the total cost per 100 pounds of each lot will be as follows: Lot I, $8.94; Lot II, $8.38; Lot III, $8.32; Lot IV, $8.49, and Lot V, $8.61. These figures would indicate a loss in all lots. Comparing the total cost including the shipping with the valuation placed on each lot, it will be noted that the loss in Lot I was 64 cents per cwt., Lot II, 8 cents per cwt., Lot III, 17 cents per cwt., Lot IV, 9 cents per cwt., and Lot V, 36 cents per cwt. On this basis Lot II was the most economical lot in the experiment, the loss on it being 8 cents per hundred or $1.022 per steer. Lot IV ranked second with a loss of 9 cents per cwt. or $1.05 per head; Lot III ranked third with a loss of 17 cents per cwt. or $2.161 per steer; Lot V ranked fourth with a loss of 36 cents per cwt., or $4.299 per steer; and Lot I came last with a loss of 64 cents per cwt., or $7.35 per steer.

Although all lots were fed at a loss, there is a marked difference in the amount of loss in each lot. Lot I, receiving the common Pennsylvania ration, showed by far the greatest loss. The total loss from feeding these twelve steers, not including pork, amounted to $88.08. This shows that such a ration is expensive and such feeding is not well adapted to Pennsylvania conditions. The next greatest loss, amounting to $51.48, was incurred in Lot V. The loss in this lot was due to the feeding of surplus protein or high-priced feed, namely, a full allowance of cottonseed meal besides 5 pounds of alfalfa hay daily per 1000 pounds live weight. Lot III ,showed a loss of $27.93; Lot IV, $12.60; and Lot II $12.26.

Although a financial loss was incurred in every lot, this is partly overcome by the value of pork produced. Owing to the limited grain ration, it was necessary to feed the hogs in the same lot some grain in addition to the feed secured from the droppings This was charged against the total amount of pork produced in each lot. After paying for this feed, the net returns from pork produced are as follows: Lot I, $13.22; Lot II, $18.48; Lot III, $10.17; Lot IV, $21.20; and Lot V, $19.98. The only lots in which the amount of pork produced is sufficient to show a gain instead of a loss are II and IV. This shows the necessity of having hogs follow the cattle, even though a limited grain ration be fed.

No account was kept of the amount of manure produced or the amount of bedding used. It is generally figured that the manure produced will pay for the bedding and the labor required to feed the cattle. It should be kept in mind that, when farm grown feeds are fed and home market prices are asked for such feeds, the labor in handling this feed when fed to live stock is no greater than the amount required to haul it to the mill or car.

The results of this experiment are not as encouraging as those of the past two years when considered from a financial point of view. Although a direct financial loss was incurred in practically every lot, it is very slight in those lots which received the more typical present day rations. With the increased price of feeding cattle, and the generally narrow margin upon which the cattle must be fed, the economy of production becomes the most important consideration. If the results of this year's test are averaged with those of previous years, it will be found that the average for these series of years will show a profit. Another factor to be kept in mind is, that the average feed commonly fed to beef cattle is roughage, which is bulky and very often not suitable for market. This experiment also shows a decided advantage in using corn silage for at least a portion of the ration, if cattle are to be fed in an economical way.

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APRIL, 1915 BULLETIN No. 134

THE PENNSYLVANIA STATE COLLEGE

SCHOOL OF AGRICULTURE

Agricultural Experiment Station

Mulch and Fertilizer vs. Tillage and Cover-Crop.
(See Table VI and Context).

Experimental Results in Young Orchards in Pennsylvania

STATE COLLEGE, CENTRE COUNTY, PENNSYLVANIA

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BULLETIN No. 134

EXPERIMENTAL RESULTS IN YOUNG ORCHARDS IN PENNSYLVANIA

BY JOHN P. STEWART.

SUMMARY.

1. The present results have been secured in experiments conducted by the Pennsylvania Station in the principal orchard sections of the state, chiefly since 1907 and 1908. These experiments as a whole cover nearly all the important phases of apple production, but the present discussion is confined largely to the results secured in young orchards during their first seven years.

2. The first of these experiments has shown, after 11 years' growth in the orchard, that there is practically no difference in efficiency between the various methods of propagation now generally used in nurseries. The results of experiments elsewhere lead to the same conclusion. On the other hand a number of considerations indicate the desirability of eliminating the seedling root entirely—thus permitting the standardization of the root-systems as well as the tops. Further work is now planned on the latter point.

3. An experiment on the value of selecting cions from trees of apparently superior qualities shows some indications in favor of the process but they are not yet sufficient to warrant definite approval of the practice. A material enlargement of this experiment has been made recently.

4. Another experiment shows that Paragon and Tolman are among the best stocks for use in top-grafting such varieties as Grimes and Tompkins King, to secure better trunks and longer-lived trees. They should also be satisfactory stocks for general use in case the selection of cions proves desirable.

5. Dynamiting in four experiments, in both young and old orchards, has failed to show any appreciable benefits during a three-year period and on a hard-pan soil.

6. The best soil management in a young orchard is the one which conserves the moisture best. This gives the largest growth and earliest fruiting under most conditions. The moisture is conserved most efficiently by a good mulch of strawy manure or other

plant materials, which should be accompanied by proper protection against mice. Where sufficient mulching materials are not available, proper tillage and cover-crops should give satisfactory results.

7. The use of tilled intercrops, such as potatoes, corn, beans, and peas, during the first seven years, has resulted in no injury to the adjacent trees even on a poor soil, and has brought in returns of $40 to $50 an acre in some years. On good tillable soil and with the trees well mulched, this is the most practical method of orchard development.

8. Among the annual cover-crops, buckwheat, hairy vetch, and millet rank high. Some financial returns can also be secured from the first, by high cutting or heading, and probably without materially reducing its favorable influence on the adjacent trees. It thus makes possible a combined cover-and-intercrop system, which apparently is a new idea in orchard development.

9. A combined mulch-and-intercrop system is also possible on suitable soils, by the use of alfalfa while the trees are young. This plant is not only capable of furnishing an abundant supply of mulching material for the young trees, but under favorable conditions it may also afford a considerable surplus for hay. The mulch, however, should be heavy enough to keep down the direct competition between the alfalfa and the principal tree roots. In our experiments, this system has given better results than any kind of annual tillage during the first seven years, and it is especially well adapted to large acreages.

10. In the older bearing orchards, where the mulch-producing area is small, three courses are available. Mulching materials may be brought in; a tillage system, preferably by discing, may be adopted; or it may be possible to replace both by a proper system of fertilization.

11. The general system of fertilization found best in our older orchard experiments involves annual applications of either stable manure, at the rate of about six or eight tons per acre, or a commercial fertilizer carrying about 6% of nitrogen, 8% of phosphorus (P_2O_5), and 4% of potash (K_2O), and applied at the rate of about 500 pounds per acre. The fertility needs are often most important in the older orchards, but a local fertilizer test on the general plan given in Bulletin 121 is advised in all doubtful cases. The manure

may be applied at any time during the spring, but it seems best to apply the fertilizer some time after the fruit has set. This incidentally gives an opportunity to vary the amounts applied somewhat in proportion to the size of the crop set.

12. On young trees, applications of plant food alone have given, as a rule, but little benefit. Such benefits as have appeared were largely in those cases where the moisture was especially well conserved or else was naturally abundant. In a few cases, some actual injury has apparently resulted to young trees from rather heavy applications of commercial materials especially rich in the more soluble forms of potash. Hence a good mulch of manure is probably the best general application for young trees. If manure is not available, moderate surface applications of the general fertilizer stated above should be satisfactory.

INTRODUCTION.

As already noted, an extensive series of orchard experiments was started by the Experiment Station in various parts of Pennsylvania in 1907-1908. The results from some of these experiments, especially those on the fertilization of mature orchards, have been published from time to time in bulletins and reports of various organizations. In the meantime, results have been accumulating in several other experiments, some of which differ considerably in subject from those already reported. The latter results for the most part are coming from young orchards which were planted expressly for use in the present series of experiments. Neither experiments nor results are yet regarded as complete, but they are presented briefly at this time to show their general trend during the first seven years, and to furnish some additional definite data in a field and for a period of development that is now relatively bare.[1]

EXPERIMENTAL RESULTS.

The first bit of data to which attention may be called is upon the comparatively old question of the relative merits of different methods of propagation for young apple trees. Which is the best type of tree to plant—one propagated on the whole root, by budding or by grafting? Or is one developed on a piece root, or without any seedling at all, equally good or superior? This was a very live question some 15 or 20 years ago, and a number of experiments were made upon it, chiefly at the Kansas, Pennsylvania, Oregon, and Alabama Stations. The last three of these experiments were practically identical in plan, the grafts being made by the Federal Division of Pomology in 1895 and the resulting trees sent to the stations for planting in 1897.

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[1] The present report of results was prepared originally for the meetings of two horticultural organizations, the reports of which are of limited distribution. It was therefore thought desirable to make it more widely available by re-presenting it with some modification in bulletin form.

Those sent to the Pennsylvania Station consisted of ten varieties of Hungarian apples, with two trees of each variety grafted on whole roots, two on top pieces, and two on bottom piece roots. They were planted on April 15 and 16 by the late Professor Butz, and cared for uniformly until the date of measurement by the writer in April, 1908, exactly 11 years after planting. Two trees were out on the latter date, one each in the first and the third groups, and one additional tree in the bottom-piece group was so dwarfed and "runty," as a result of defective union, that it was excluded in the final averages. The average growth made in the various groups, in 11 years, is shown in Table I.

Table I.—Influence of Method of Propagation Upon Growth of Apple Trees.

(Average Size and Height of Trees, after 11 years in orchard, 10 varieties of 6 trees each)

Kind of Graft	No. of Trees	Average Trunk Girth	Average Height	Gain in Girth	Gain in Height	Rank
		In.	Ft.	%	%	
Whole root..........	19	15.85	13.86	0.2	0.4	2
Top piece...........	20	16.12	14.10	1.9	2.2	1
Bottom piece........	18	15.82	13.80	...	...	3

In this case it will be noted that the trees propagated on the top-piece roots are slightly in the lead in all respects, with those on the whole roots coming second. In the experiment in Alabama, as reported in Bulletin 98 of that Station, the trees on the bottom pieces were showing a slight superiority at the close of the second season, with those on the top pieces second, and the whole roots third. In the Oregon experiment, as stated in the Oregon Annual Report for 1901, pp. 38 and 39, the trees on the whole roots were slightly ahead at the close of the fourth season, in the single variety remaining at that time, with those on the top-piece again second.

In the Kansas experiments, reported in Kansas Bulletins 65 and 108, 64 trees grafted on whole roots averaged just one-tenth of an inch larger in trunk diameter, at the end of ten years' growth in the orchard, than 30 trees that had been budded in the usual manner on whole roots. They in turn averaged a fifth of an inch larger than 102 trees, involving some additional varieties that had been propagated on piece roots. No differences in growth or vigor were observable in the orchard. In another experiment in the same state and reported in Bulletin 65, three varieties of 400 trees each, on whole roots, were compared by Judge Wellhouse with an equal number of trees of the same varieties propagated on very short piece roots,—two-inch lengths. In the latter case, the young trees had developed a very considerable number of roots directly from the cions above the seedling pieces, thus placing the trees on their own roots to a considerable extent, while no cion roots were developed on the whole-root trees. At the end of 19 years of growth in the orchard, the only difference observed had been in the much greater number of sprouts that had come up from the whole-root trees. No other noticeable difference, either in growth or fruiting, had appeared.

From all these data it is obvious that no one of the present forms of propagation has any material advantage over any other. It may be of distinct advantage to get rid of the seedling root altogether, either by using the shortest roots practicable and then cutting them off entirely during the process of transplanting after roots have developed above, or possibly by a direct rooting of the cions by the use of a method that has been used successfully by certain men in the Federal Bureau of Plant Industry.

This elimination of the seedling root would at least relieve us of the numerous ill-effects of poor unions. It would also reduce the opportunity for crown-gall infections, eliminate the possibility of harmful influence of the variable seedling stocks upon the cions, and would make it possible to develop definite and standard root-systems, with which the injuries from root-aphis and kindred difficulties might well be greatly reduced or entirely eliminated. This is evidently an important array of advantages, all of them practical and by no means impossible of attainment. It simply requires more work along these definite lines to carry this matter through, and that is already under way.

On the Value of Cion Selection.

The next question is somewhat related to the one just considered, but is much more recent in origin. It bears upon the value of cion selection, including the so-called "pedigreed" trees, and also incidentally includes the existence of the so-called drone trees. In this question, we are seeking to determine whether or not it is possible materially to affect the yield or any other important quality in an apple tree by selecting the cion which produces it from a tree known to possess the desired qualities to an unusual degree.

Various theories and observations have been advanced on this question, and a few experiments have been conducted. Most of these are summarized by the writer in the Annual Report of this Station for 1910-11, pages 493-500 and 505-6. The net results of all this observation and discussion, however, have shown merely that important variations do exist among mature apple trees, in almost any direction desired, but thus far none of the variations within a variety have been actually proved to be heritable, with the apparent exception of color. In addition the most fundamental and generally accepted theories are all against such inheritance, without excepting color.

With this situation in view, we started a preliminary test in 1908 on the influence of cion selection in improving yields. The individual trees in this case were chosen merely on the recommendation of commercial growers for the most part, and without any definite and comparative records covering several years, which is the only satisfactory basis for making the primary determination of what are really superior individuals. This defect is being remedied in another, much more comprehensive test recently started.

In the present test however, the cions from the supposedly superior individuals were top-grafted chiefly on Northern Spy stock, and ordinary nursery trees of the same varieties were planted alongside for comparison. It is naturally much too early to draw any conclusions from this work, but the results to the close of the seventh year are now given so that the present status of the experiment may at least be known and that later and more conclusive results may be anticipated. The relative yields from the two classes of trees are shown for eight varieties in Table II.

Table II.—Influence of Cion Selection on Yields of Young Apple Trees. Expts. 334 and 335.

(Yields of eight varieties in pounds, 1914, seventh year)

Variety	Nursery Trees			Trees from Selected Cions		
	No. of Trees	Yield lb.	Average lb.	No. of Trees	Yield lb.	Average lb.
Grimes	9	0.0	0.00	26	14.5	0.56
Rome Beauty*	4	16.0	4.00	13	132.5	10.15
Smokehouse	4	31.0	7.75	4	51.0	12.75
R. I. Greening	5	0.0	0.00	4	6.0	1.50
Tompkins King	5	0.0	0.00	16	0.0	0.00
Esopus	5	0.0	0.00	4	0.0	0.00
Sutton	5	0.0	0.00	3	0.0	0.00
Jonathan	5	8.25	1.65	16	5.75	0.36

*Five trees from W. J. Green omitted here.

In the first four of these varieties, a slight superiority is now being shown by the trees produced from the selected cions. In the Rome Beauty comparison also, the selected-cion group has consistently shown much more blossoming for the last three years, but 1914 is the first year that any measurable quantity of fruit has set. In the next three varieties no advantage is shown in either group, although the cions for these trees were secured from one of the most prominent advocates of the present practice; and in the last variety the slight difference shown is in favor of the unselected nursery trees.

These results are evidently insufficient either to approve or condemn the practice of cion-selection. In the upper portion of the table there is some indication of a possible advantage in it, but neither these nor any other data now available are sufficient to warrant any one in paying materially higher prices for the so-called "pedigreed" trees. Such trees may have more certainty of trueness to name, where the cions have come recently from mature trees of known bearing habits, and one is naturally on the safe side of the question in using them, when they can be obtained without material increase in price. This, however, is all that can be said at present in favor of the practice so far as apples are concerned, and much more data are needed.

Relative Value of Certain Stocks in Top-Grafting.

In case any of the experiments on cion selection should definitely prove the practice to be advisable, it will evidently be well to know something of the relative values of various stocks available for use in top-grafting. Some desirable varieties also should regularly be top-grafted to secure better and healthier trunks. To secure data on the relative merits of certain well-known varieties for stock purposes, a test was started in 1908, using four trees each of three varieties top-grafted on five different stocks, with the results shown in Table III.

Table III.—Influence of Various Stocks on Growth of Young Apple Trees.

(Average increase in trunk-girth 1908-1914, Expt. 334)

Plat	Stock	JONATHAN	TOMPKINS KING	GRIMES	General Aver. Gain in Size	Gain Over Lowest
		Average Gain	Average Gain	Average Gain		
		In.	In.	In.	In.	%
1	Northern Spy..	7.99	6.71	7.25	7.32	11.4
2	Tolman........	6.79	6.82	8.60	7.40	12.6
3	Wolf River.....	6.25	6.37	7.09	6.57	....
4	Paragon.......	9.22	8.56	8.75	8.84	34.5
5	Champion.....	7.29	6.78	7.83	7.30	11.1
6	Nursery Trees..	8.33	6.62	6.09	7.01	6.7

One rather unexpected result appears here in the fact that in all cases except one (those on the Wolf river), the trees top-grafted on known stocks have made a better average growth than those grafted on seedling roots in the nursery. In the case of the Grimes also, all the top-grafted trees are now in the lead. Among the various stocks, the trees developed on the Paragon are now distinctly in the lead, with those on Tolman coming second. With the Grimes and the Tompkins King, which are the only varieties of these three that really need top-working, the superiority of these two stocks is very marked so far as growth is concerned. In smoothness of unions, the Tolman and the Champion are probably best, with the Paragon next, if the top-grafts with Jonathan be excepted, as with that variety the Paragon stock has tended to outgrow the cions. Incidentally, the reverse is the case with Grimes on Wolf River.

The Northern Spy stock has averaged third in growth and is now running about equal to the Paragon in unions. It also usually makes an excellent trunk and root-system, but in at least one respect it is considerably less desirable than either Tolman or Paragon for stock purposes; namely, in its unusual tardiness in starting growth in the spring. This tends to make the cions of most varieties more active than the stock, which is naturally the reverse of the condition desired when the grafts are being started. From the present results, therefore, either Paragon or Tolman appears to be distinctly preferable to any of the others, for Grimes at least, —with Champion coming in third, if the Jonathan grafts are omitted.

Some further interesting relations between certain stocks and cions used in top-grafting have been reported orally to the writer by Samuel Fraser, of Geneseo, N. Y. Mr. Fraser finds, for example, that the Twenty-Ounce top-grafted on Baldwin makes from 50 to 100% better trees in five to eight years than when worked on Northern Spy. Similarly he finds that the Wealthy does very poorly on R. I. Greening, while the latter does very well on Wealthy. Hubbardston cions top-grafted on Ben Davis, Northern Spy, and Tolman resulted in such peculiar changes in twig color—some becoming red, some purple, etc.—that they could not be used with safety for further cion wood until they had proved their identity by coming into bearing.

These and similar facts indicate that many of the common variations in size and vigor so frequently shown by the same variety of trees, both in their nursery and later growth, are due to differences in congeniality between the cions and the variable seedling roots on which they were worked. Moreover, the very remarkable effects of certain types of grafting, which result in the plant chimeras and graft hybrids (See Journal of Heredity for December, 1914, pp. 521-546), also indicate that there is still a vast amount to be learned about all these matters, which again brings us back to the desirability of reducing all variable factors, such as seedling stocks, to the lowest terms possible, where uniformity is the aim.

On the Value of Dynamiting in Apple Orchards.

This question was naturally not considered of fundamental importance, but there was so much agitation and there were so many inquiries about it, that it seemed desirable to get some definite data concerning it. For this purpose four experiments were started in the western part of the State on a Volusia silt loam which had a typical hard-pan subsoil at an average depth of about 10 to 14 inches. Two of these experiments were on orchards just being planted, and two on 25-year-old Baldwin, which had become more or less sod-bound. They were started in the spring of 1912 under the writer's general direction. W. R. White of the College took all the records. The net results in the young orchards at the close of the third season are shown in Table IV.

Table IV.—Influence of Dynamiting on Growth and Vitality of Young Apple Trees.

(Average gains in trunk-girth, etc., in 2 Expts. 3 yrs., 1912-14)

Experiments In	White Orchard	Johnston Orchard
No. of trees dynamited, (A)....	34	25
No. of trees not dynamited, (B).	19	10
Depth of explosions............	2 to 4 ft., by 6-inch intervals	Same
Average gain in girth, (A)......	2.01 in.	2.491 in.
Average gain in girth, (B)......	1.98 in.	2.486 in.
Benefit to growth in (A)........	1.5%	0.2%
Total trees dead, (A)...........	8 or 23.5%	0
Total trees dead, (B)...........	2 or 10.5%	0 (1 weak)

In both these cases we find a very slight superiority in growth in favor of the dynamited trees, but no gain of importance. In fact the difference is so very small that it is necessary to go to the third decimal place to find it in the Johnston orchard, and in the other orchard the higher death rate among the dynamited trees much more than offsets the slight superiority in growth of those that lived. In fact, the difference in death rate seems to be the only definite effect that has appeared here so far, as the growth differences are so small as to be capable of explanation by normal variations between the two groups of trees. Similar results on the apple are reported from both the New Hampshire and the New Jersey Stations, and the general absence of effect in the thorough, physical, subsoiling test—started at the Missouri Station in 1895 and reported in 1900, Bulletin 49—all lead to the conclusion that nothing important is likely to be gained by these methods.

In the mature orchards, the results to date are shown similarly in Table V.

Table V.—Influence of Dynamiting on Yield, Growth, Color, and Average Size of Fruit on Mature Apple Trees.

(Total yields, growth, etc., in 2 Expts. 3 yrs., 1912-14)

Experiments In	Boak Orchard	Johnston Orchard
No. of trees dynamited, (A)..........	5	5
No. of trees not dynamited, (B).......	5	5
Depth of explosions..................	2 to 4 ft., by 6-inch intervals	Same
Total yields in (A)....................	3986 lb.	5654 lb.
Total yields in (B)...................	5136 lb.	5332 lb.
Benefit to yield, in (A)................	-22.4%	6.0%
Benefit to growth, (A).................	4.9%	-0.7%
Benefit to color of fruit, (A)...........	0.4%	-12.4%
Benefit to average size of fruit, (A)...	-7.3%	10.1%
No. of fruits in samples..............	1189	939

Here again the results are so variable as to cause one to conclude that the dynamiting has had little or no definite influence at all. In fact, the net effect in both experiments is rather more against the shooting than in favor of it. At any rate, none of the present results would indicate any special value in the practice of dynamiting in apple orchards. The same is true of the definite experimental results elsewhere, so far as the writer is aware. Incidentally, there are already enough of really definite and profitable uses for dynamite to make it unnecessary to try forcing it into a use for which it is apparently not fitted.

On Methods of Handling the Soil in a Young Orchard.

The next three experiments bear upon the various methods of handling the soil in an apple orchard from the time of planting up to the age of seven years. The first and the third experiments are chiefly concerned with the relative values of various cultural methods and cover-crops, while the second furnishes some data also on the relative values of various fertilizer combinations.

The data shown in Table VI are obtained from the experimental orchard at the College. In this experiment the area now covered by plats 2 to 6 was plowed in the fall of 1907, and prepared about as for corn in the spring of 1908, when all the trees were

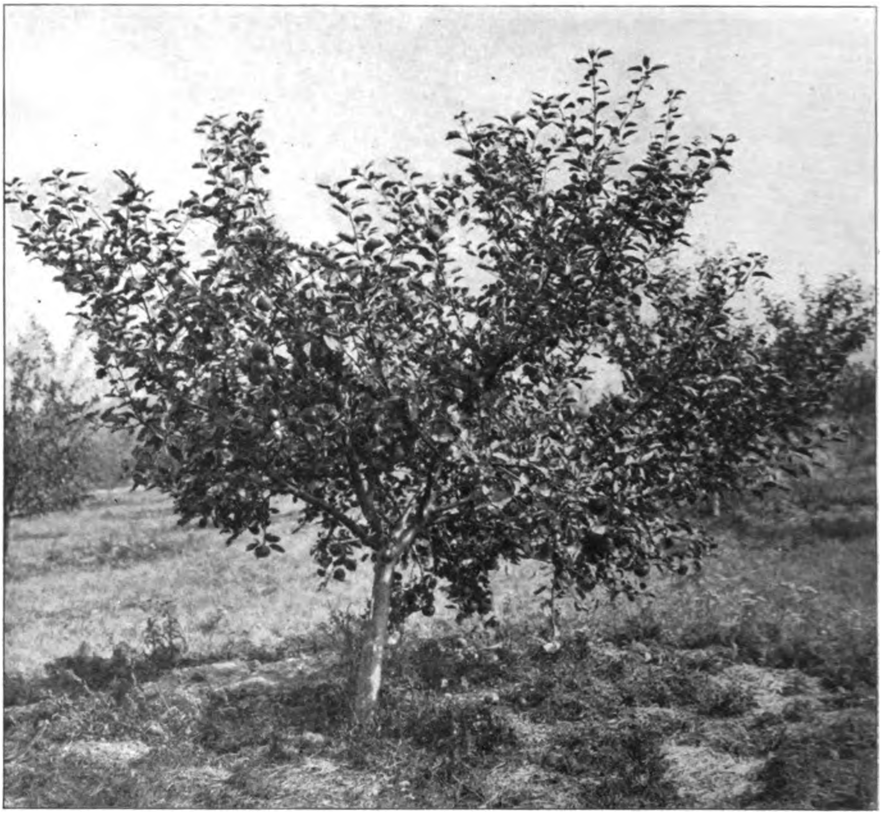

Fig. 1—A Typical Baldwin of Plat 9, Receiving Mulch and Fertilizer.
This tree yielded 61 pounds of fruit in 1914. It was top-grafted to Baldwin in 1909 on Northern Spy set the year before. (See Table VI and context).

planted. Since then the several methods named in the table have been followed annually, in 45-tree plats, each involving three varieties of trees.

In the meantime, in plats 7 to 9, no tillage of any kind has been given. The trees were merely planted in the rather thin sod, in holes dug with a spade, and then were mulched with about 100 pounds of straw to the tree. Since then the growth between the trees has been cut at least twice annually, and the material obtained in the first cutting has been added to the mulch, while the second was left where it fell. In addition, the initial mulch of outside materials has been repeated about every other year. The results at the close of seven years are shown in Table VI.

Table VI.—Influence of Cultural Methods on Moisture, Growth, and Yield in a Young Orchard.

(Results from Expt. 331, first seven years, 1908-14)

Plat	Treatment	*Moisture Content 1913	Relation to Optimum Content	Average Gain in Girth	Gain Over Tillage	Total Yield 1914	Gen'l Rank
		%	%	In.	%	Lb.	
2	Tillage	10.6	53.0	6.84	....	1.5	8
3	Tillage and intercrop	5.5	27.6	7.69	12.4	21.6	6
4	Tillage and cover-crop	8.5	42.7	6.84	....	7.0	7
5	Cover-crop and manure	9.2	45.9	8.31	21.5	135.4	3
6	Cover-crop and fertilizer	9.4	47.2	7.76	13.5	18.9	5
7	Mulch	17.1	85.6	8.29	21.2	38.5	4
8	Mulch and manure	18.2	90.8	8.76	28.1	300.5	2
9	Mulch and fertilizer	18.1	90.4	8.93	30.5	390.1	1

*Determined by J. W. White of the Department of Agronomy and R. H. Bell of Exp'tl Pomology

In the first place, it will be noted that the least growth is being made in plats 2 and 4. The annual cover-crop, which consists of a mixture of red and crimson clover, has therefore shown as yet no benefit to the trees. The use of a tilled annual intercrop, in plat 3, followed by a late cover-crop of rye, has not only resulted in no apparent injury, but the trees on this plat are actually making nearly 12½% more growth than those under either of the more usual treatments in plats 2 and 4. Similar results are observable in the experiments shown later in Table VII. Like results were also obtained by Emerson at the Nebraska Station and reported to the close of the second year in 1903, in Bulletin 79, pages 14 to 17.

The financial returns from the intercrops in our experiments, with potatoes, have usually run from $40 to $50 an acre, even on the very poor soil involved. The intercropping method therefore is evidently by far the most practical of any of those involving tillage. No important injury should result to the associated trees, so long as suitable intercrops are used. By suitable intercrops we mean those involving some early season tillage each year. If in addition the trees themselves can be kept mulched with a good coat of strawy stable manure, such benefits as those shown in plat 5 can be secured.

Where tillage and intercrops are not feasible however, the mulch system is available and has proved very effective, as shown in plats 7 to 9. The results there are in accord also with others stated in the following table, and with those reported from the Ohio Station in Bulletin 171. The special success of the mulch is

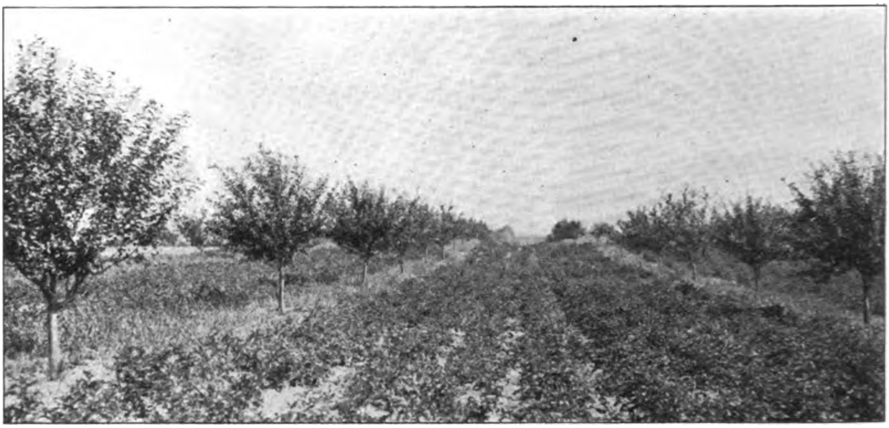

Fig. 2—Potatoes as an Intercrop in Plat 3 of Expt. 331, in 1914.
The tilled intercrop system accompanied by proper fertilization is the best and most practical method of orchard development, whenever it is available.

evidently due to the unusual effectiveness in conserving moisture. As shown in the second column of Table VI, the roots of the mulched trees were surrounded with 85 to 90% of the best possible moisture content for the particular soil involved, even in September, 1913, after fully six weeks of very unusual drought, while the soil around the roots of the tilled trees in most cases had been reduced to a dust-dry condition.

The addition of plant-food in plats 8 and 9 has resulted in some gain over the mulch alone, but from the relative growth made, it would seem that the conservation of moisture is more than twice as important as applications of plant-food, at least in the case of young trees. The latter applications, however, have apparently had considerable influence on the yields, which is rather surprising in view of the fact that the trees are so young. Incidentally, the usual correlation between yield and growth is especially prominent here, and this again emphasizes the fact that early bearing cannot be secured on young healthy trees without an extra amount of growth.

In Table VII, we have results from another experiment, started at the same time as the last, on a Volusia silt loam in the western part of the State. This experiment differs slightly from those foregoing in the fact that the cultural methods and the fertilizer treatments are separated, and the latter treatments so enlarged that the relative values of the different fertilizer elements can be determined to some extent. Just at present, however, its chief value is in the general corroboration that it gives to the results in the preceding table.

Table VII.—Influence of Fertilization and Cultural Methods on Growth and Yields in a Young Orchard.

(Average increase in trunk-girth, first seven years, and yields in 1914, Expt. 337)

Plat	Treatment	Average Gain in Girth	Gain Over Normal Growth	Yields 1914**
		In.	%	Lb.
1	Check (Untreated)	6.64	....	32
2	Nitrogen and phosphorus	7.59	11.8	62
3	Nitrogen and potash	6.96	0.3	10
4	Check	7.09	....	0
5	Phosphorus and potash	7.69	6.2	17
6	Complete fertilizer	8.67	11.4	28
7	Check	8.18	....	37
8	Manure	8.77	10.0	23
9	Lime (and NPK, 1912-)	8.18	5.3	17
10	Check	7.56	....	10
11	Tillage and cover-crop	7.38	1.5*	19
12	Tillage and intercrop	7.79	7.2	50
13	Clean tillage	7.27	....	23
14	Sod mulch	8.11	11.6	109

*Gains over lowest in the cultural method section.
**Reduced to equivalent plats throughout.

In the cultural plats 11 to 14, the greater growth and bearing in the mulch and the intercrop treatments are again evident. In the fertilizer portion of the experiment, the growth has been improved somewhat more than usual by certain elements, viz., nitrogen and phosphorus. This is probably connected with the fact that this particular soil type is usually deficient in these two elements. In general also, it is very well supplied with moisture, which probably accounts for the relatively smaller effect of the mulch in this case.

Relative Value of Cover-Crops.

When these experiments were started, we naturally expected the tillage and cover-crop method to rank high among the soil treatments. Especially was this expected in young orchards. To get some data, therefore, as to which cover-crops were best for this purpose, the experiment shown in Table VIII was started. Along with the comparison of annual covers used in plats 1 to 12, a single permanent cover was included in plat 13, and the material annually produced between the rows was used as a mulch around the trees. The results to the close of the seventh year are shown in Table VIII.

Table VIII.—Influence of Cover-Crops on Growth and Yield of Young Apple Trees.

(Results in Experiment 333. 1908-1914)

Plat	Treatment	Average Increase in Girth	Gain Over Lowest	Estimated Bloom 1914	Yield 1914	General Rank
		In.	%	%	Lb.	
1	Medium red clover........	7.60	13.1	0.3	0.00	8
2	Mammoth clover	7.17	6.7	0.0	0.00	11
3	Alsike....................	6.85	1.9	0.2	0.00	12
4	Crimson clover...........	7.77	15.6	0.2	1.25	7
5	Hairy vetch..............	8.07	20.1	0.5	0.50	3
6	Cowpeas (Black)..........	6.72	0.0	1.0	0.00	13
7	Soybeans (Hollybrook)....	7.98	18.8	0.2	0.00	5
8	Oats and Canada peas....	7.93	18.0	1.5	0.00	6
9	Rye.......................	7.52	11.9	0.2	0.25	9
10	Millet	8.02	19.3	0.3	1.25	4
11	Rape and turnips.........	7.29	8.5	0.2	0.50	10
12	Buckwheat...............	8.15	21.3	0.1	0.50	2
13	Alfalfa (used as mulch)....	8.83	31.4	15.0	8.75	1

In this case also it is a notable fact that the mulched and the untilled trees associated with the permanent cover of plat 13 are again in the lead. In addition to this, the alfalfa has produced all the mulching material required and some surplus besides, especially in the earlier years. The mulching, moreover, has always been heavy enough to keep down practically all growth immediately above the majority of the feeding roots of the trees. This is probably essential for best results with this plant as the permanent cover because of its special affinity both for moisture and soil nitrogen.

In a good alfalfa soil, however, it is possible to get an abundant mulch of this sort and still have a considerable surplus of good hay besides. In other words this particular method gives us a mulch and something of an intercrop at the same time, without any tillage and without any apparent injury to the trees, where mulching and protection against mice are both sufficient. This, it will be observed, is a relatively new idea in orchard development, and the present method, or some modification of it, is evidently very well adapted for large acreages, or for places where tillage and intercrops are not available.

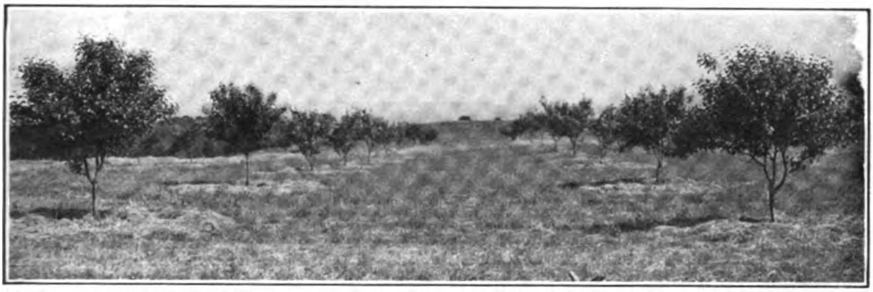

Fig. 3—Alfalfa as a Permanent Cover and Mulch Producer, in Expt. 333, in 1913.
This is a very satisfactory method of orchard development for large acreages, or where tillage and intercrops are not desirable.

A similar new idea is suggested by the results in the adjoining buckwheat plat. The trees in this plat are now showing the best gains of any of the annual tillage treatments. This may be due partly to a slight advantage that it apparently has in location, but without that advantage the buckwheat treatment evidently would still rank high. It is also probable that the general good effects of this plant as a cover-crop are not dependent in any way upon the return of the grain to the soil. It therefore might well be harvested by heading or high cutting and thus give us the unusual example of a combined cover-crop and intercrop, which also exerts no apparent ill-effect on the trees. This crop, moreover, is especially good where an orchard is being developed on so-called "new ground," and something is desired to keep down the second growth of sprouts and underbrush.

The vetch continues to show a better effect on the adjacent trees than any other of the annual, legume covers. This is not surprising when its nitrogen-fixation, its shading habit of growth, and its very low moisture demands are recalled. This plant also shows considerable promise for use as a permanent cover and mulch producer. It usually forms an abundance of seeds by the middle of July or earlier, after which it can be cut and left where it lies for awhile for reseeding, and then be brought up around the trees as a mulch. Running over the loose vetch with a heavy roller or some similar implement before raking it around the trees often assists in shelling the seeds out where they are wanted, and a light discing or harrowing after the raking may be helpful in increasing their germination.

Among the non-leguminous plants, the high rank of the millet and the buckwheat is still evident. The same is true of rape when used alone. We are unable to give any very satisfactory explanation for this, but the facts themselves are sufficient to attract favorable consideration to the use of these species as cover-crops. This is especially true when their relatively low seed-cost is considered. The buckwheat is probably best from the economic standpoint, as noted above, but the millet is very satisfactory where this use of buckwheat is not available.

The seeding rates, relative cost in 1914, and general dates and methods of seeding, that we have followed in the annual cover-crops, are shown without further comment in Table IX.

Table IX.—Rate of Seeding and Cost of Cover-Crop Seed in 1914.

Crop	Rate of Seeding, lb. per A	Cost of Seed per lb.	Cost of Seed per A.	Date of Seeding	Method
		Cents			
Crimson clover.....	20	6½	1.30	July 15-20	Broadcast and harrowed
Medium red clover.	12	15	1.80	July 15-20	Broadcast and harrowed
Mammoth clover...	15	15	2.25	July 15-20	Broadcast and harrowed
White clover.......	5	30	1.50	July 15-20	Broadcast and harrowed
Alsike..............	6	17½	1.05	July 15-20	Broadcast and harrowed
Sweet clover.......	25–30	25	5.25 to 7.50	Jan. to May	Broadcast and harrowed
Hairy vetch........	40	7 to 12½	2.80 to 5.00	July 15–Aug. 15	Drilled or broadcast
Canada peas.......	60–90	......	......	July 15–Aug. 15	Drilled or broadcast
Cowpeas (Black)...	50–60	5	2.50 to 3.00	June 25-30	Drilled
Soybeans (Hollyb'k)	40–50	4½	1.80	June 25-30	Drilled
Rye................	90	1.3	1.17	Sept. 1–Oct. 15	Drilled or broadcast
Oats...............	75	1.5	1.13	July 15–Aug. 15	Drilled or broadcast
Millet..............	20	4	.80	July 15–Aug. 15	Drilled or broadcast
Buckwheat.........	1 bu	3	1.50	July 4–10	Drilled or broadcast
Essex rape.........	8	6	.48	July 4–10	Broadcast and harrowed
Cowhorn turnips...	4	25	1.00	July 4–10	Broadcast and harrowed

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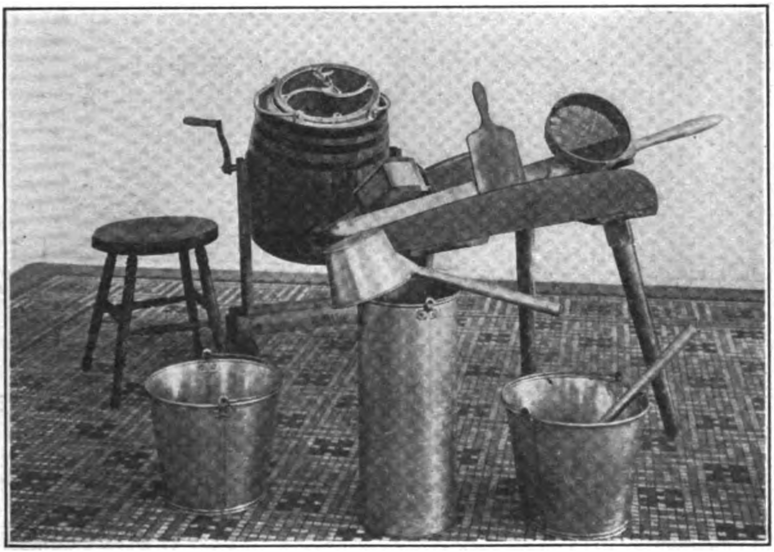

(Farm Butter Making Apparatus)

A Study of the Manufacture of Dairy Butter; Methods of Making Farm Butter

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BULLETIN No. 135

A STUDY OF THE MANUFACTURE OF DAIRY BUTTER

BY E. L. ANTHONY

SUMMARY.

1. Several educational contests conducted among the dairy buttermakers of Pennsylvania in connection with these studies show that there is a great lack of uniformity in farm butter. They also show that the average percentage of moisture in farm butter is very low.

2. The variations found in farm butter are to some extent due to the churns used, but are more especially due to the methods now used in churning and in the handling of the cream during the ripening process.

3. Overripened cream does not produce butter of as good quality as cream ripened to the proper degree. Creamery operators are inclined to use a lower degree of acidity in churning cream than was formerly used, and these studies indicate that this is advisable for farm butter as well. It is advised that cream be not ripened to more than .5 per cent of acid; as little as .3 per cent is sufficient under average farm conditions. Butter with lower acidity is being demanded by the market.

4. Attention to the following details of handling farm cream will afford better results than the present methods: Cool all cream down to 45 degrees; add each gathering, stir and hold the cream at this temperature until enough is secured for churning, and then warm it up to 75 degrees and allow .5 per cent of acid to develop;

Or ripen the first gathering at once to .3 per cent of acid, then cool to cellar or holding temperature, and add the additional gathering, after it has been cooled, to the already ripened cream;

Or use a good starter or small amount of butter-milk in the first cream gathering, keeping the latter as cool as possible until it is ready to churn; if the cream ripens too slowly warm until .5 per cent of acid is developed. The use of butter-milk as a starter may, however, injure the keeping quality of the product.

5. Butter should be carefully worked. Butter not sufficiently worked will be gritty and mottled; overworked butter will be weak in grain and body.

6. To secure good butter from farm cream, care and cleanliness must be observed in the handling of the cream, in the churning and working operations, and also as to the temperatures used.

7. If considered desirable a high moisture content can be secured as well in farm butter as in creamery butter, if care is used in regulating the period of churning as well as the temperatures used.

8. These studies show that with the common hand butter-worker moisture is gradually lost as the working progresses, while with the combined churn the moisture increases after a certain period in working the butter.

STUDIES IN FARM BUTTER.

During 1913 four educational butter-making contests were conducted by the Dairy Department of The Pennsylvania State College for the makers of farm butter throughout the State. The purpose of these contests was two-fold: (1) To study the quality of the butter made on the farm and its method of manufacture and to suggest methods of improvement; (2) to secure enough samples of farm butter to afford an accurate knowledge of the present quality and character of this product. The facts secured afforded a basis for studies to improve the quality and to secure uniformity of product, and brought out many points of value to dairy butter-makers.

CONDENSED REPORT OF THE FOUR CONTESTS SHOWING THE WIDE VARIATION FOUND.

	April	June	August	October
No. of Samples..................	63.0	53.0	37.0	34.0
Score 90, or above...............	42.0	30.0	24.0	21.0
Highest Score....................	92.5	92.5	92.5	93.0
Lowest Score.....................	80.0	86.0	85.0	85.0
Average Score....................	89.7	89.6	89.8	89.9
Highest Salt.....................	9.1	5.4	4.8	4.5
Lowest Salt......................	.45	.4	1.3	.2
Highest Moisture.................	16.8	15.6	15.4	15.3
Lowest Moisture..................	8.0	8.0	8.0	6.6
No. of poor or ill-shaped packages	34.0	25.0	12.0	8.0
No. of neatly-packed samples....	29.0	28.0	25.0	26.0

While many of the samples were received in good condition, yet in the first contest, as the table shows, there was much lack of uniformity in the style of package.

The common criticism made by the judge of the samples submitted was the great variation in the flavors, much of the butter being found defective through tainted condition or old age of cream used. The table also shows a wide variation in moisture and salt contents. The description accompanying each sample as to method of manufacture clearly indicated that there is a great contrast in the practices now in use on farms. These differences in method are no doubt the cause in part at least of the inequalities found in farm butter.

There is a great demand for knowledge about farm butter-making. This is due in a large measure to the great amount of farm butter made in this State. Pennsylvania occupies first place in the production of dairy butter. In 1909 there were made 61,138,000 pounds of farm butter, valued at $15,668,000.00.

With the numerous large markets within easy reach of nearly every farm, the present large production could be increased if the uniformity of the butter could be maintained and the quality improved.

Farm butter is often discriminated against on the market because of its lack of uniformity in flavor, body, salt, moisture, and package.

EXPERIMENTAL WORK.

The experimental work related to two operations: (1) The handling of the cream and milk before churning; (2) the churning and working of the butter.

As to the first operation the following points were considered:

1. The effects of different amounts of acid in the cream before churning.

2. The effects of different methods of holding and ripening cream for farm butter-making.

3. The effects of different kinds of starter used in ripening cream.

As to the second operation the points considered were:

1. The effects of the different kinds of churns used.

2. The effects of different end points in churning.

3. The effects of various degrees of working upon the butter.

4. The variations caused in churning as the rise in temperature, amounts of salt and moisture in the butter, and the loss of fat in the butter-milk.

5. The best point at which to stop churning farm cream.

6. The moisture percentage in farm butter at the different steps in manufacture.

EFFECTS OF DIFFERENT CHURNS USED.

The object of this experiment was to show the variations found between the different styles of common farm churns, as to the percentages of moisture and salt secured in the butter as well as the length of time required for churning, the amount of fat left in the butter-milk, and the average rise of temperature of the butter-milk during churning.

With the three churns used, the method of procedure was exactly the same. For each test a quantity of ripened cream ready for churning was divided into three parts, one part being used for each churn. The temperature of the cream and of the wash water and the amount of the latter were the same in each case; and the butter was worked in the wash water the same number of times, as well as in the same manner, as nearly as possible. The results given below are the average for ten churnings in each churn:

Observations.

Kind of Churn	Butter		Time of Churning	Rise of Temperature Deg. Fahr.	Fat in Butter Milk %
	Moisture %	Salt %			
Barrel, (5 gal.)	13.39	4.0	40 min.	54 to 60.3	.19
Swing churn (4 gal.)	13.5	3.8	47 min.	54 to 61.0	.229
Combined churn and worker (18 gal.)	13.6	2.45	29 min.	54 to 59.0	.18

These results show that the combined churn and the barrel churn churned somewhat closer than the swing churn, thus leaving less butter-fat in the butter-milk. This is probably due to the character of the agitation within the former two churns and to the fact that the temperature of the cream rose less during churning. The granules, after butter started to break, gathered more slowly than in the other churn. This permitted better separation of the fat from the butter-milk before the granules became so large as to require the stopping of the churning.

The moisture content averaged a little higher in the butter from the combined churn. This is probably due to the fact that the butter in this type of churn is worked in the water. This water is expelled from the butter during the working and is held in the churn instead of being allowed to run off, as is the case when butter is worked on a common hand-worker. After partial working, the butter begins to reincorporate or take up this moisture.

There was a smaller rise in the temperature of the cream during churning in these two churns. It was difficult to keep the temperature of the cream in the swing churn used from rising too high during churning because the lid, which is only set on the churn, allowed air from the room to circulate within the churn. A churn which holds the cream near the temperature at which the churning was started is preferable, because the butter comes out firmer, and is, therefore, more desirable to work.

ACIDITY VARIATIONS IN CREAM.

The object of this experiment was to determine what percentage of acid in the cream is best for churning under farm conditions. A quantity of sweet cream of average quality was taken from the general supply furnished the college creamery and divided into five equal parts.

The first part was cooled at once to churning temperature, held for two hours, and then churned. The acid test made when the churning was begun gave .2 per cent.

The second part was ripened at 75 degrees until it had developed .3 per cent of acid, after which it was cooled at once to churning temperature, held for two hours, and then churned.

The third part was treated in the same manner as the second, except that it was ripened to .4 per cent of acid.

The fourth part was treated in the same manner, except that .5 per cent of acid was developed before churning.

The fifth part was held at 75 degrees until it had developed the fullest possible amount of acid, which was found to be .85 per cent. It was held seventy-two hours at that temperature and was then cooled down to the churning temperature, held two hours more, and then churned.

The procedure was the same for all the churnings. A temperature of fifty-two degrees was used, the temperature of the wash water being fifty-four degrees. In the table below are given the scorings made by the judge, Mr. C. F. Fryhofer, Federal Butter Inspector. The salt and moisture content also are given. These butters were held a month in the refrigerator at forty-five degrees and again scored to see how they kept. The results are given in the second table.

First Scoring.

Acidity in Cream	.2%	.3%	.4%	.5%	.85%
Moisture, %	13.2	13.4	13.3	12.8	15.5
Salt, %	2.5	1.7	2.1	1.5	1.5
Fat in butter-milk, %	.52	.23	.20	.25	.4
Score	89	91	92	92	86
Criticism	Tainted	Mild flavor	Slightly old flavor	Slightly old flavor	Cheesy, old, due to old cream

Second Scoring (4 weeks later).

Acidity	Score	Criticisms
.2%	85	Undesirable flavors, old, tainted.
.3%	88	Old flavor, tainted.
.4%	87	Old, tainted flavor, peculiar flavor.
.5%	87	Old, tainted flavor.
.85%	84	Very old, tainted, rancid flavor.

The decrease in the quality of the butter caused by holding the cream too long before churning is very well shown in the foregoing table. It will be noticed that the flavor increased up to about .4 per cent of acid, when it began to deteriorate and to take on old and stale cream quality. The reason for the low score on the sweet cream was probably due to the fact that it had not been given a chance to develop desirable flavors to counteract the odors imparted to it by the cows or the barn. So these taints were not masked in the butter. These taints were lost or overcome in the lots where the cream was allowed to sour slightly.

This experiment suggests that cream should not be allowed to develop more than .4 to .5 per cent of acid before it is churned. Cream held at 70-75 degrees for ten hours will develop under normal conditions about that amount of acid. It will be slightly thick and noticeably sour.

Methods of Cream Ripening.

One of the chief causes of poor flavor or quality in farm butter is the method used in holding or ripening the cream previous to churning. With conditions so different on each farm it is hard to set a definite rule by which cream can be cared for; the same one will not apply to all conditions. Most farm cream is held or handled in farm cellars, springs, or milk-houses, and usually at a temperature of about 50-60 degrees. It is common farm practice to hold it at this temperature until enough is secured for a churning, when it is warmed and held until sufficiently sour, and then churned. Butter made from cream handled in this way is often criticised as having an old or stale cream flavor.

Some authorities have asserted that at about 50 degrees we have the best growing temperature for the undesirable fermentations in the cream, and that the characteristically old or stale cream flavor is due to these types of bacteria.

The following experiment upon methods of handling cream before churning was made to determine what practicable method best avoided these undesirable qualities:

1. Holding cream below 45 degrees until enough was secured for churning, adding each day's gathering and stirring, and when enough was secured raising the temperature to 75 degrees, and ripening over night or until .5 per cent of acid was developed.

2. Ripening the first gathering by holding it at 75 degrees until .35 per cent of acid was developed, and then cooling to cellar

temperature (55 degrees), and adding each gathering after cooling directly to the first; and so on until enough had been secured for a churning; then churning the whole without further ripening.

3. Adding a quart of good butter-milk to the first gathering, adding each subsequent day's gathering to that, and holding all at cellar temperature until enough was secured for a churning; if not sour enough then, ripening by warming to 75 degrees until .5 of acid was developed, and then churning.

4. Holding the gatherings at 55 degrees until enough was secured for a churning.

The cream used in all churnings came from the same source. The churnings were conducted as nearly as possible in the same manner. Four repetitions were made at intervals of about a week apart. The average results were as follows:

Methods of Holding Cream.

Methods	Percentage of acid when churned	Scorings of butter from churnings				Score after one month for churning No. 1 and 2	
		1	2	3	4		
	Average					No. 1	No. 2
Held at 45 degrees	.52	92½	91	91½	91	90	90
Ripened at 75 degrees, then held at 55......	.55	93½	92	93	92	89	90
Held at 55, butter-milk added	.57	93½	91½	94	91	86	87
Held at 55 until churning secured	.42	92	90	90	91	84	86

These results indicate that methods Nos. 1, 2 and 3 are superior to No. 4 in securing good quality in butter. They also indicate that for keeping quality the butters from methods Nos. 1 and 2 were much superior to those from Nos. 3 and 4. This is probably due to the better control of the desirable types of bacteria in these former two methods.

THE EFFECTS OF METHOD AND AMOUNT OF WORKING ON QUALITY OF BUTTER.

The object of this experiment was to determine the effect of the manner and amount of working upon the body, appearance, uniformity of color, and salt distribution of butter.

This study was suggested by the large amount of farm butter which is weak in body, mottled in appearance, and contains salt in a gritty condition.

For this experiment butter was taken from three churnings made by each of the three churns used.

The conditions were the same in all cases. Samples were taken at the 12th, 16th, 20th and 24th working of the butter and were examined as to quality:

Effect of Working Upon Quality of Butters.

Barrel Churn.		
After 12 workings,	Badly mottled	Gritty
After 16 workings,	Badly mottled	Not gritty
After 20 workings,	Mottled	Not gritty
After 24 workings,	Not mottled	Not gritty
Swing Churn.		
After 12 workings,	Badly mottled	Not gritty
After 16 workings,	Slightly mottled	Not gritty
After 20 workings,	Slightly mottled	Not gritty
After 24 workings,	Not mottled	Not gritty, slightly greasy
Combined Churn.		
After 12 workings,	Mottled	Gritty
After 16 workings,	Slightly mottled	Not gritty
After 20 workings,	Not mottled	Not gritty
After 24 workings,	Not mottled	Good body, not gritty.

This study shows that the mottles in butter largely disappear after about 16-20 workings on the board and that the body of the butter is much better than with a lesser number of workings, being closer in texture and carrying less loose water. The grittiness of salt disappears at about 16-20 revolutions of the worker, this fact showing that about that amount of working is necessary properly to incorporate and to secure uniformity in the distribution of the salt.

It must be remembered that this discussion of the amount of working applies to the particular conditions of temperature, etc., mentioned. If the butter had been colder, the room cooler, and the salt cold or of poor grade, further working would have been necessary to overcome mottles. Differences in the quality of the butterfat, such as differences which may be caused by feed, seasons of the year, etc., will affect the working requirements of the butter.

Churning Factors Which May Cause Poor Quality or Lack of Uniformity in Butter.

The purpose of this experiment was to determine how far the common defects in uniformity and quality of farm butter, made from good farm cream, could be overcome by control of the churning conditions.

In the studies of farm butter it was deemed best to take some cream in ordinary farm condition and to try to secure a first class butter from it by controlling the factors in churning that were thought to be causing a lack of uniformity and quality in farm butter.

Farm cream was taken as it was brought into the college creamery. This cream was selected from the general supply of sour cream delivered by patrons; therefore, it fairly represented an average of sour farm cream. It showed upon test 0.5 per cent of acid. The churning process followed strictly the general directions given in another part of these studies for the production of uniform farm butter.

The butter was scored by a Federal Butter Inspector, as were all other samples in these studies. The results given in the table below are the averages from three churnings with each churn, made in such manner that the cream from a single day's supply was used with each of the churns. These churnings were made during June, 1913.

Qualities of Butter From Farm Cream.

Churn	Moisture	Salt	Score
Barrel	14.2	2.7	90
Swing	13.8	1.05	90
Combined	14.8	1.87	90½

These results show that butter with a moderately high moisture content may be secured from average cream. The moisture content seems to be most influenced by the manner of churning and working, rather than by the kind of churn used. The quality also is somewhat influenced by the method of making as well as by the condition of the cream used.

Moisture and Uniformity of Quality Control in Farm Butter.

The object of this experiment was to produce, if possible, from cream handled and churned under farm conditions, butter of good quality and of moisture content approaching that usual in creamery butters, and to show the degree of uniformity in butter quality that can be secured with different styles of churns.

Farm butter as well as creamery butter has been under inspection by the United States Department of Internal Revenue with regard to its moisture content for many years. It is necessary for the farm butter producer to consider the factors that influence the moisture content in his product. It is claimed by some that butter with high moisture content is superior in flavor and handling quality to butter containing a very low moisture content. This matter is of importance also because the quantity of butter made depends to a certain extent upon its moisture content. The incorporation of an excessive amount of moisture in butter is not advocated, especially if its purpose is to secure a larger quantity of butter, and quality should never be sacrificed to quantity; nevertheless a higher moisture content than is now usual can be carried in the average farm butter without sacrificing quality in the least.

This experiment shows, in fact, that with the larger amount of moisture secured the quality of the butter improved; but butter which contains 16% or more of moisture is classed as adulterated butter and subjects the maker or dealer to a fine.

These churnings were made during the summer, June 1 to August 15.

A quantity of cream was taken directly from the separator. This cream was allowed to ripen at a temperature of seventy-five degrees until it had developed .6% acid; it was then cooled to the churning temperature that was to be used (fifty-two degrees), and held at that temperature for three hours, when it was divided into three lots and churned in the barrel churn, the combined worker churn, and the swing churn, respectively. The cream was churned until the granules were the size of a small grain of corn; the butter-milk was then drawn off and an amount of wash water equal to the original volume of cream was placed on the butter in the churn. The butter was given fifteen revolutions in the wash water and the latter was then taken off. This process left the butter in the loose, granular form and in a quite firm condition. In the case of the swing and barrel churns, the butter was then placed on a hand-worker, spread out loosely, and three-fourths of an ounce of fine butter salt for each pound of butter-fat was spread evenly over it. The butter was then worked by using the sharp side of the worker, and by cutting rather than mashing it. As soon as the butter was thus spread out over the board, it was piled up from the ends with a paddle and again worked with the lever. This method was continued until the lever had been used sixteen times. By this time the butter was free of all excess water; it had assumed a rather dry appearance, and the grain showed a steel break, that is, the butter was compact and uniformly fine in grain. It was printed in regular pound prints, held in the refrigerator for six days, and then scored by a Federal Butter Inspector. The cream used was of a good grade, and it was handled in such manner as to assist the development of the proper kinds of fermentation which helped to prevent it from acquiring objectionable odors and taints.

The scores given, with the percentages of moisture obtained, as well as the details of the making, are presented below:

Observations.

	Barrel Churn	Swing Churn	Combined Churn
Condition of cream	.6 acid	.6 acid	.6 acid
Time required to ripen	8 hrs.	8 hrs.	8 hrs.
Time held	3 hrs.	3 hrs.	3 hrs.
Per cent fat	28 %	28%	28%
Approximate fullness of churn	⅓	⅓	⅓
Temperature at which churned	52°	52°	52°
Time to churn	45 min.	40 min.	30 min.
Size of granules	Pea	Pea	Pea
Temperature of butter-milk	58	59	58
Amount of wash water	30 lbs.	30 lbs.	35 lbs.
Temperature of wash water	54°	54°	54°
Revolutions in wash water	15	15	18
Revolutions on worker	16	16	18
Score of butter	91	91	91
Per cent moisture	14.8	12.4	14.7
Per cent salt	2.7	1.9	2.6

The moisture content was much higher than that commonly found in farm butter, the average being 13.9 per cent for the three churnings, while the average of over sixty samples of butter made on farms throughout the State and tested at this Station was only 11.9 per cent, after short keeping under conditions not favorable to evaporation.

In the case of the small combined churn, the butter was handled in the same manner as with the other churns, except that it was salted and worked in the churn. One and one-quarter ounces of salt per pound butter-fat was used, as the butter was worked with the gate to the churn closed and the water that was worked out of the butter in the churn was thus held. This excess water readily takes up some of the salt, hence more salt must be used to get the proper amount into the butter. It was possible to work the butter longer in the churn, because it was protected from the warm air of the room and did not become warm so quickly. It was worked eighteen revolutions instead of sixteen, as in the case of the other churns.

Since butter begins to reincorporate moisture after about the fourteenth working, an advantage is gained by giving it further working in the water of the churn, and in this way securing a greater overrun.

The butter-maker should use a churning temperature sufficiently low to produce a butter firm enough to stand the longer working in the churn.

Stages of Moisture Changes in Farm Butter.

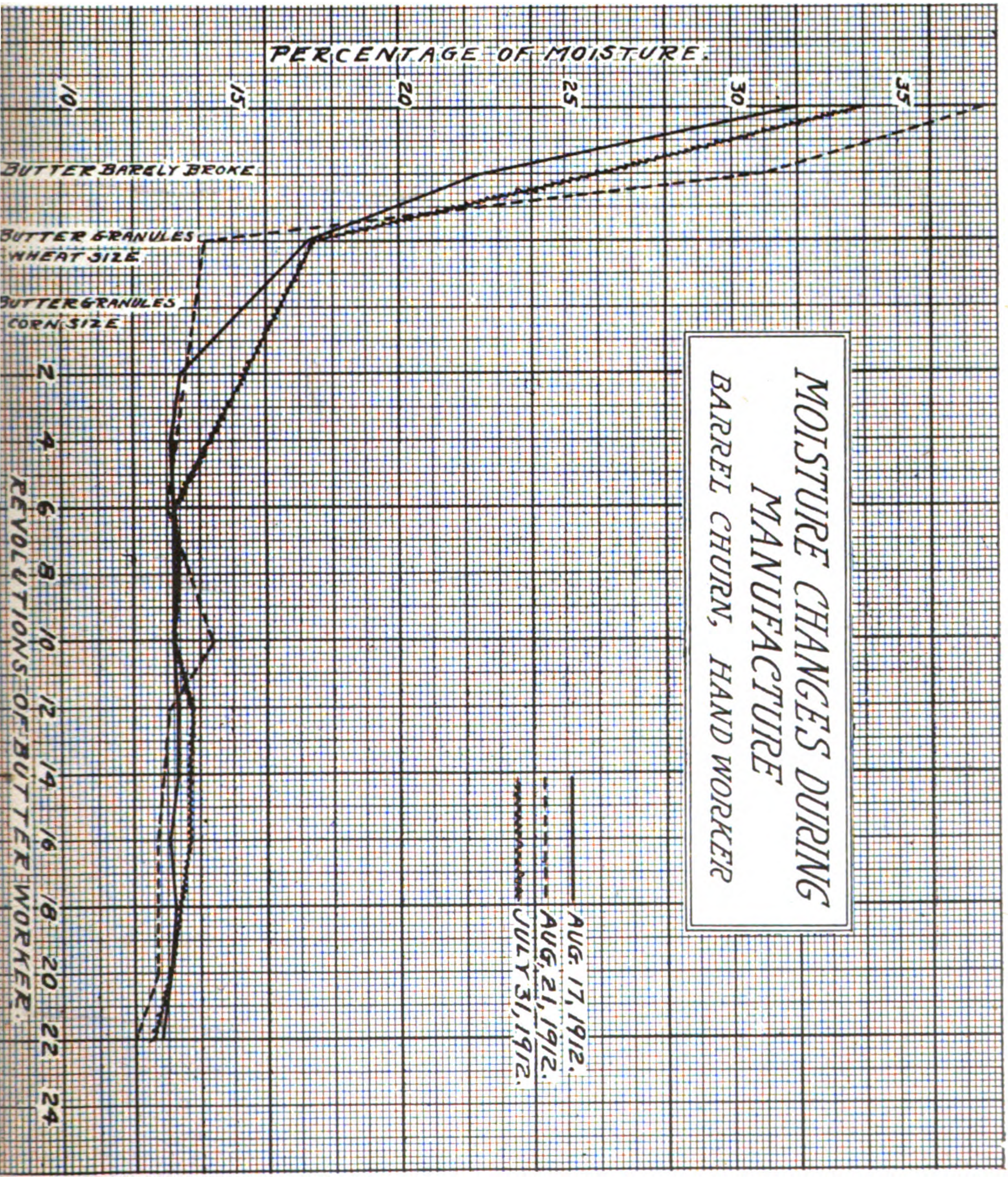
This experiment was made to determine the moisture changes in farm butter as the working progressed. Samples were taken from the churn before salting and also at every two revolutions of the worker until the butter was considered finished. The moisture percentages for each of the three churns are given in the table which follows. They are based on the average of three churnings from each churn:

Observations.

Condition of Butter	BARREL CHURN Per cent moisture				SWING CHURN Per cent moisture				COMBINED CHURN AND WORKER Per cent moisture			
				Av.				Av.				Av.
Broke......	37.6	34.4	32.8	34.93	29.2	....	30.0	29.60	21.0	....	26.0	23.50
Wheat-size..	30.8	26.8	22.6	26.73	....	....	....	.....	22.6	20.2	18.4	20.40
Corn-size...	14.2	17.6	17.4	16.40	15.4	....	17.8	16.60	17.4	16.4	14.4	16.06
2 Workings.	....	....	....	.....	....	....	....	.....	....	13.6	13.2	13.40
4 Workings.	....	....	13.4	13.40	....	....	....	.....	....	13.2	13.2	13.20
6 Workings.	....	....	13.2	13.20	....	....	....	.....	....	13.0	13.4	13.20
8 Workings.	13.0	13.2	13.2	13.13	12.8	14.2	13.6	13.53	13.0	12.8	12.8	12.80
10 Workings	13.8	13.4	13.2	13.46	13.8	....	13.2	13.50	....	12.6	13.2	12.90
12 Workings	14.6	13.2	13.2	13.66	12.6	....	13.4	13.00	12.8	....	13.2	13.00
14 Workings	13.2	14.0	13.4	13.53	12.6	....	13.4	13.00	12.8	13.4	13.8	13.00
16 Workings	13.0	13.8	13.4	13.40	13.6	14.0	13.8	14.80	12.6	....	13.8	12.70
18 Workings	12.8	13.8	13.2	13.26	13.6	....	13.2	13.40	12.6	....	13.0	12.80
20 Workings	12.8	13.6	13.4	13.26	13.6	13.6	13.2	13.26	12.6	13.8	13.4	13.20
22 Workings	12.8	13.0	13.2	13.00	13.4	13.4	13.0	13.26	12.8	13.8	14.2	13.60
24 Workings	12.2	12.8	....	12.50	....	....	12.8	12.80	....	....	14.2	14.20
26 Workings	....	....	....	.....	....	12.8	....	12.80	....	....	....	.....
40 Workings	....	....	....	.....	....	....	....	.....	....	14.8	....	14.80

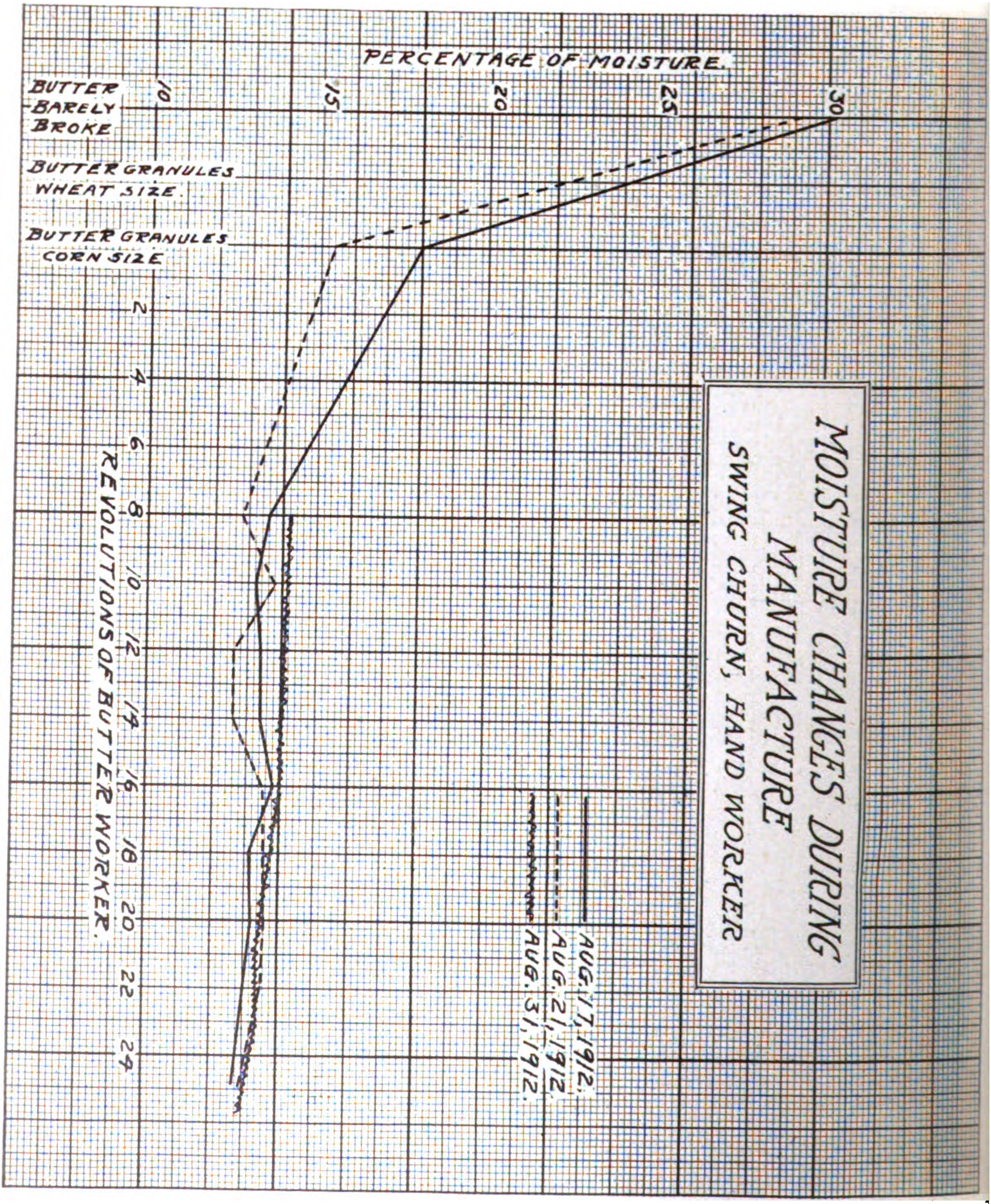
By these churnings it is shown that just as the butter starts to "break" it contains a high per cent of moisture, but that this varies greatly in percentage in the same and in different churns. This is due probably to the difficulty in securing the exact size of granules each time. This seems contrary to the opinion that butter contains more moisture in the corn-kernel stage than in the wheat-grain stage. More moisture is here shown in the wheat-grain stage. It seems that in the case of all three churns the moisture content of the butter drops quite uniformly until the beginning of the working. In the case of the swing and barrel churns, the butter was worked on a table-worker which caused the moisture to drop slightly as the working progressed. This is caused by the water running off as the butter is worked. This water is lost to the butter or there is less moisture in the finished product. This seems to be true of all hand-worked butter in cases where the water that is driven out of the butter runs off the working board.

In the case of the combined churn, the change in moisture content was very much the same as with the other two types of churns, until the working of the butter was commenced. After the butter had been worked from about 16-20 revolutions it began to take up moisture. The water that was previously expelled from the butter was still held in the churn and came into contact with the butter as it was being worked, and was gradually incorporated



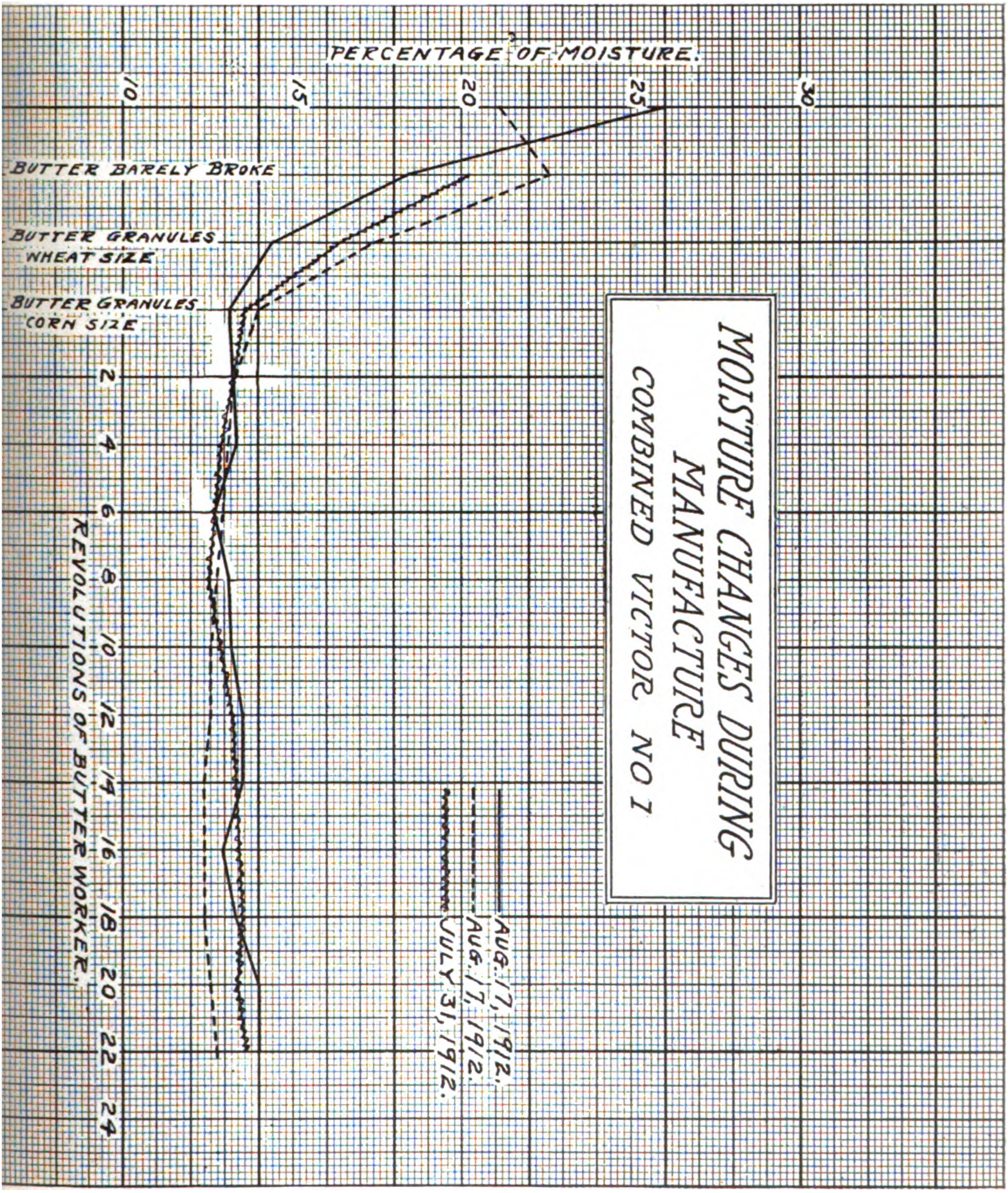
MOISTURE CHANGES DURING MANUFACTURE

BARREL CHURN, HAND WORKER



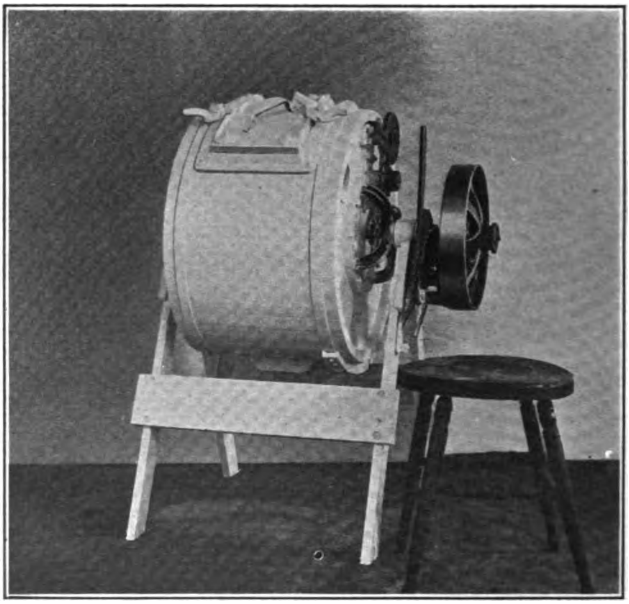
MOISTURE CHANGES DURING MANUFACTURE

SWING CHURN, HAND WORKER


MOISTURE CHANGES DURING MANUFACTURE
COMBINED VICTOR NO 1
PERCENTAGE OF MOISTURE.
10
15
20
25
30
BUTTER BARELY BROKE
BUTTER GRANULES WHEAT SIZE
BUTTER GRANULES CORN SIZE
2
4
6
8
10
12
14
16
18
20
22
24
REVOLUTIONS OF BUTTER WORKER.
AUG. 17, 1912.
AUG. 17, 1912.
JULY 31, 1912.

to a small extent; thus the moisture content was temporarily raised, though it was again lowered as the working progressed further.

This experiment seems to show that the combined churn has the advantage in yield over the other churns with which the table-worker was used in controlling the moisture content of the butter.



Small Combined Churn and Worker.

One significant fact is brought out with respect to the three churns. The moisture content rose in all cases where the butter was worked from about eight to twelve times. This is hard to account for unless at this point the salt had begun to be uniformly distributed through the butter and acted momentarily to delay the working out of the moisture. The salt at this point probably began to absorb moisture and had a tendency to draw the excess moisture into the butter.

DIRECTIONS AND METHODS SUGGESTED FOR MAKING UNIFORM DAIRY BUTTER OF GOOD QUALITY

HANDLING CREAM.

The production of good butter of uniform quality starts with the cow. Milk from unhealthy cows can never be made into first-class products. Nor can cows that are kept in unclean, insanitary places produce clean milk.

The maker of butter on the farm can have complete control of his milk from the time it is drawn from the cow until it is made into butter. This is not true of the creameryman or manufacturer, who has to secure his product from outside sources over which he has no supervision. This advantage which the farm butter-maker possesses means much to him if he realizes it and makes the most of it.

The cows should always be brushed off and kept clean at milking time. Care should be taken that all utensils be kept clean and in good condition, so that the cream, whether skimmed or separated, shall be good, clean, sweet and not absorb any undesirable taints or odors. Much butter which would otherwise be good is damaged in flavor because care is not taken to keep dirt and impurities out of it. Milk which is not separated by a cream separator should be at once cooled by some suitable method and held as cold as possible until the cream has risen. As soon as the milk is separated the cream should be cooled as low as possible.

PERCENTAGE OF FAT IN CREAM.

If a separator is used the percentage of fat in the cream may be regulated. When it is impossible to test the cream for its percentage of fat, regulating the separator, so that about 12-14 per cent of the total milk is separated and comes out as cream, will give approximately the proper richness to the cream. The best results will be obtained when the cream has about 28-30 per cent of fat;

cream with too high a percentage of fat has a tendency to adhere to the sides of the churn, which causes difficult churning and increases the danger of loss of fat in the butter-milk.

When the cream is too thin or has too small a percentage of fat in it, as in the case of hand-skimmed cream containing from 12-20 per cent of fat, good, uniform churning is hard to secure. Such cream loses too much fat in the butter-milk and also requires longer churning.

METHODS OF RIPENING.

Probably no other one factor is so largely the cause of poor quality in farm butter as the lack of proper ripening previous to churning. On the farm it is often necessary, in order to secure a sufficient amount for a churning, to store the cream from two or more days' milkings. The common method now in use on most farms is simply to collect in a cream can or jar successive creamings, until enough has been secured for a churning. The cream is meanwhile held in the cellar, milk-house, back porch, or spring house. The temperature at which it is held varies with the weather, season of year, and other conditions. The cream under these conditions usually ripens or develops acid until at the end of three or four days it becomes sour, and is then stirred and churned. If it is kept too cold for ripening during this holding period, it is warmed for several hours, and allowed to sour before churning.

This practice is a bad one, as it occasions many of the taints and off flavors found in farm butter. The reason for this is that the temperature of the cream is usually about fifty-five degrees, which is a little too low to secure a good growth of the lactic or acid-forming bacteria which produce the proper flavors in the cream. It is claimed by some that at this average cellar temperature there are present the proper conditions for the growth of the bacteria that produce objectionable flavors and taints in cream. These undesirable bacteria produce no acid, will not grow well in the acid medium, and seem to grow best at a temperature of 50°-60°.

The rest of the experimental work carried out to determine the best way to ripen cream on the farm indicates that there are three other methods, any one of which will give better results than the storing of cream at cellar temperatures. They are: (1) Holding or storing the cream at a very low temperature (below forty-five) until enough is secured for a churning, and then warming it up to 70°-80°, and ripening; (2) ripening the first collection of cream at once and adding each skimming to it, from day to day, until a churning is secured; (3) adding a portion of butter-milk to the first cream gathered and then adding each skimming until enough is secured for a churning.

The first method is a good one for butter-makers who have ice for keeping the cream cold. The method is to cool to forty-five degrees or below immediately after separating each day's cream gathering, and to hold the total amount at this low temperature until enough is secured for a churning. The cream for the churning is then warmed up to seventy-five degrees and held until the proper amount of acid is developed in it. By holding the cream at seventy-five degrees under these conditions for about twelve hours, the proper percentage of acid will usually be developed.

The second method advocated is ripening at about seventy-five degrees until .3 per cent of acid is developed in the first separation that is to form the new churning, then cooling this down to the temperature of the spring house or cellar, and adding each creaming, after it has been cooled, to this lot until enough is secured for a churning. This will, under average conditions, give about enough acid development in the whole churning for best results. The ripening of the first separation of cream develops a large number of lactic acid bacteria and produces some acid, which serves to hold in check the undesirable types of bacteria.

The third method is to add a portion of butter-milk of good quality to the first separation; and to add the succeeding creamings and hold the whole amount at cellar or spring house temperature until a sufficient quantity is secured for a churning. If the ripening has not sufficiently developed by that time, the temperature can be raised to seventy-five degrees, and the cream allowed to ripen to the proper amount of acid.

The object in the last two methods is essentially the same—to hold in check undesirable bacteria by having developed or introduced into the cream a preponderance of the desirable bacteria and a small amount of acid. The latter two methods are simple, handy, and require no special apparatus. Care must be taken, however, in the last method to make sure that the butter-milk comes from butter of a good flavor and quality. The using of butter-milk of medium or poor quality is very likely to produce butter of much the same kind as that from which the butter-milk was secured.

AMOUNT OF ACID TO DEVELOP, OR DEGREE OF RIPENING.

Large amounts of farm cream are ripened or soured too much before churning. Because of this it develops an old and tainted or stale flavor. Cream ripened until it is sharply sour contains usually from .6 to .8 per cent of acid, which is too much. The best flavors and keeping quality seem to be secured when it is ripened about .4 to .5 per cent of acid. Where no acid test is used, this amount of acid may be approximated. The cream should taste only very mildly sour. Cream naturally ripened at 70°-75° will develop about this amount of acid, if held ten hours.

THE USE OF STARTERS.

Starters are not much used on the farm and when used are generally of the natural kind, that is, made up of butter-milk or good sour milk. They are very desirable, if care is taken to use only good butter-milk or sour milk, and will in most cases improve the quality of the butter produced. They are especially desirable when cream is hard to churn because of improper ripening, and where it is difficult to secure proper ripening. The amount to use varies with the condition of the cream, but from 10-20 per cent is a suitable quantity in most cases.

The natural starter made from sour milk is perhaps the best for farm conditions. To make it, set several samples of good, clean skim or whole milk in small jars until the milk becomes sour. The holding temperature should be about seventy degrees. When the samples have become sour, they should be examined. They should have a good, smooth curd formed free from gas bubbles. The flavor and taste should be clean and sharply sour. The sample showing the best flavor and condition of the curd should be selected for the starter. It may be built up in larger quantitites by adding the sample to about ten times its volume of clean, sweet skim-milk and allowing the mixture to stand at about seventy degrees until it has coagulated. This coagulated milk is then the starter to use in the cream-ripening process. It contains a preponderance of the desirable lactic bacteria which are necessary for that process.

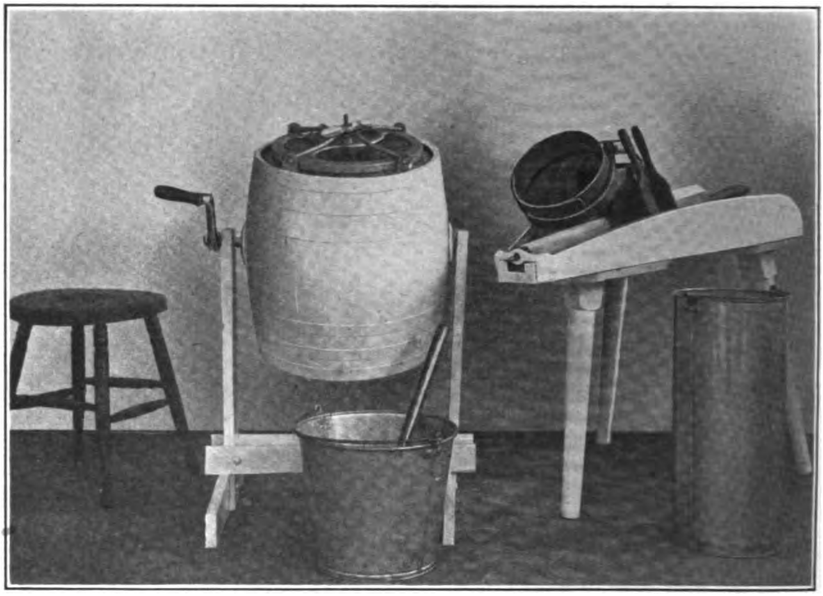
The amount of starter to add to cream varies from 8 per cent to 50 per cent. If the starter is a good one, the more added the better, but if too much be added it will dilute the cream too greatly and make it hard to churn. About ten per cent is a common amount to use.

CHURNING TEMPERATURE.

The temperature at which cream is churned is very important. When the cream has been ripened properly, it should be cooled down to the temperature at which it is to be churned and held at that temperature at least two hours to allow the fat to become cool and firm enough to churn.

The churning temperature varies widely. It is affected by the season of the year, kind of feed given the cows, condition of the cream, and temperature of the churning room.

In the spring and summer, when the cows are fresh and the feeds succulent and soft, the butter-fat is naturally softer than later in the season, so that a lower temperature should be used, about 52°-56° being proper under average conditions for these seasons. This temperature should be increased to about 56°-60° in the winter. Much cream is now churned on the farms at above 60 degrees. Experiments seem to indicate that the lower temperatures are to be preferred, as butter is much firmer when coming from the churn, does not so easily incorporate butter-milk, and will



Barrel Churn and Hand-Worker.

stand more working, thus producing a better body and a more uniform quality. Because of the cream being poorly ripened or abnormal in some way, it is often necessary to use higher temperatures than are here given. When difficulty in churning is experienced, the cream should never be raised in temperature by adding hot water to the churn, but should be poured from the churn into a can and gradually raised a few degrees in temperature by setting the can in a pan of warm water. (For difficult churning see last page of bulletin).

CHURNING AND KIND OF CHURN.

The proper care of cream in the ripening process, although very essential, does not insure good butter. Good cream can easily be spoiled in churning. Unless the churn is kept in good condition it is impossible to make good butter with it. The churn should always be well scalded out and well cooled down before using. There are two reasons for this; first, the hot water will kill many bacteria that may be growing in the wood and will close the pores of the wood so that the cream or butter will not adhere to it; second, so that the temperature of the cream will not be raised while churning and yield soft, greasy butter.

While many churns have been invented, there are few that meet with general approval and use. The best churn for average farm use is one that is very simple, easy to keep clean, and durable. The common barrel churn meets all these requirements and is a general favorite on the farm. There are several other types used in large numbers, such as the swing churn, dash churn, and combined churn and worker. In selecting a churn, great care should be taken to secure one which will not excessively agitate the cream, thus causing poor body by incorporating butter-milk in large quantities in the butter.

In general a churn of ample capacity, made of hard wood, free from peculiar odors or taints, sanitary in construction, and easy to cleanse should be selected.

LENGTH OF TIME TO CHURN.

The length of time best for churning varies with the condition of the cream, but ranges from fifteen to thirty minutes. If the cream churns in less than fifteen minutes, the butter is very likely to be too soft to work well and will have a poor body when finished. Cream that requires much longer than thirty minutes may be improperly ripened or abnormal in some way. Taking the cream from the churn and raising the temperature in the manner suggested above will in most cases overcome the trouble.

The churning should stop when the butter begins to collect in the butter-milk in granules from the size of a pea to that of a grain of corn. Granules of this size do not contain so much butter-milk as do larger ones. The butter is easier to wash, salt, and work.

WASHING OF BUTTER.

It is a common practice on the farm to wash butter through several wash waters. This is unnecessary, if the churning has been stopped at the right time. If the granules range in size from pea to corn grains, one washing will remove all the butter-milk. Too much washing has a tendency to give the butter a flat taste, by removing the finer flavors. Use about the same amount of wash water as of cream churned.

The temperature of the wash water varies considerably, but it should not be much higher or much lower than the churning temperature. Very cold wash water is to be avoided, as cold water absorbs the flavors of the butter readily, causes brittleness of body, and poor quality in the butter.

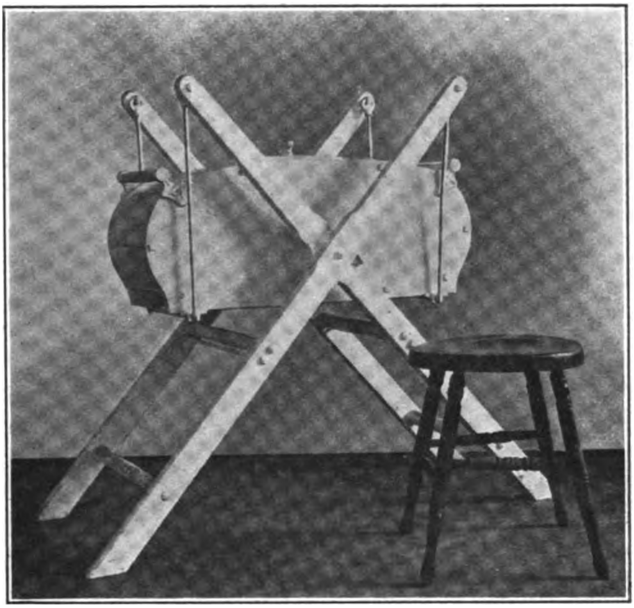
Where a low churning temperature is used, the washing temperature may be the same as that for churning, and it should never be more than four to six degrees less. Where a higher temperature is used for churning the washing temperature may differ as much as from 4 to 10 degrees from that of the churning. The wash water should be pure and clean, and free from odors or taints, as they will be readily absorbed by the butter.

WORKING AND SALTING THE BUTTER.

After the wash water is drawn from the butter—unless a combined churn and worker is used—the latter should be taken out in the loose, granular form and placed on the working-board or table. This table should be scalded and thoroughly wet with cold water. Butter will stick to dry, warm, or dirty boards.

To the butter on the working-board fine dairy salt of the best quality should be added. The quantity varies with the taste of the maker and the markets on which the butter is sold, but, under average conditions where the butter is worked on a hand-worker, three-fourths of an ounce of salt to each pound of butter-fat is a desirable amount to use. A larger amount, from the above to one and one-quarter ounces of salt per pound of butter-fat, must be used in the combined churn. This larger amount is necessary because of the wash water which is held in the churn.

After the salt has been evenly distributed over the granules of butter, the working should commence. It is a common practice to let the butter stand with the salt on it for a while before working.



Small Swing or Cradle Churn.

This is unnecessary if the butter is in a good granular condition, firm in body, and the salt fine and of a good grade.

The working should be given by first using the sharp edge of the worker to cut and flatten the butter out into a thin sheet. This sheet should then be folded to the center of the working board, and the process repeated.

The working of butter accomplishes three important things: It evenly incorporates the salt, excludes the excess water, and makes the body compact. The working should be continued until the excess water no longer appears, and the salt is worked evenly through the mass. The texture of the body may be ascertained by breaking off a piece of the butter. The break should show a brittle, grainy appearance, similar to that of broken steel.

PRINTING AND WRAPPING.

When the butter has been sufficiently worked it should be printed into some desirable shape. The common rectangular one-pound mold is the best to use, as it makes a neat, attractive print and is easy to handle.

After the butter is printed it should be wrapped in a good grade of parchment butter paper. This is very essential. Much butter is wrapped in cloth or oiled paper. This is a bad practice, as the cloth may hold molds, which readily grow and produce taints and odors. The oiled paper, if kept for any length of time in a warm place, becomes very rancid and imparts undesirable flavors.

It is always advisable to have the name of the producer or his farm name on the wrapper of the butter, if it is sold on the market. If the butter is of good quality this will tend to increase the sales and be an incentive to the highest effort for maintaining uniformity in quality. The attractiveness and neatness of the package always helps to sell the butter, often at much above the average market price.

THE CARE OF FARM CHURNS AND APPARATUS.

After the butter is taken from the churn, the latter should be rinsed out with warm water, and the rinsing followed by a thorough washing with very hot water. The rinsing out with warm water will remove any butter-milk which may remain in the pores of the wood. The hot water will remove any fat which may be left in the churn.

It is never well to use soap powders on the interior of the churn, but the occasional use of a small amount of dairy washing powder or lime water is beneficial.

To keep the churn sweet and free from odors and taints a small handful of lime placed in some water in the churn or in the last rinsing of the churn is very effective. It is very essential in good butter-making to see that all apparatus used is absolutely clean and free from undesirable odors and taints, as these are quickly absorbed by the butter.

Temperature, care, and cleanliness are three vital factors in good butter-making.

Sci 1638.5.4

AUGUST, 1915 BULLETIN No. 136

THE PENNSYLVANIA STATE COLLEGE

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Agricultural Experiment Station

Collar-Blight and Related Forms of Fire-Blight

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BULLETIN No. 136.

COLLAR-BLIGHT AND RELATED FORMS OF FIRE-BLIGHT

BY C. R. ORTON AND J. F. ADAMS.

INTRODUCTION.

The forms of disease of the apple, pear, and quince caused by the fire-blight organism are the most serious troubles with which the Pennsylvania apple grower has to contend. That form of blight which attacks the trunk of the tree near the ground, and which may be known as collar-blight, is especially troublesome. The fact that published information on collar-blight and its related forms is not readily available for many orchardists makes it seem advisable to issue the present bulletin on the subject.

HISTORY.

Collar-blight in Pennsylvania was first brought to the attention of the Experiment Station[1] by an orchardist in Franklin County, where it had appeared in a block of fourteen-year-old apple trees. It undoubtedly was prevalent in the State for some years previous to this time, but owing to the relatively slight attention previously given to commercial apple culture in Pennsylvania its presence was overlooked. With the awakened interest in fruit growing and the recognition of the importance of cultivation and fertilization in orchards, especally favorable conditions were brought about for the development of this disease, and it was soon recognized. Some of the old orchardists of the State claim that the disease has existed in Pennsylvania for fifty years, but the earliest authentic record obtained from correspondence with orchardists places its inception at about 1900.

That the disease is not a local one is shown by references to it in the published reports and bulletins of several State experiment stations and it would seem now to be rather widespread in New York, New Jersey, Pennsylvania, Maryland, Virginia, West Virginia, Ohio, Illinois, and Oregon. It probably occurs to some extent in nearly all of the apple-growing sections of the United States. What is apparently collar-blight is referred to by Selby[2] in Ohio as destructive to Grimes Golden, Tompkins King, and other varieties of apple. Whetzel[3] refers to collar-blight in the following words: "The large cankers at the bases of young trees, frequently referred to by growers as 'collar-rot', are in many cases very probably due to the same causes as that of the cankers on the upper parts of the tree."

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[1] Stewart, J. P. Pear Blight on Apple Trees. Rural New Yorker, 66:765. 1907.

Grossenbacher[4 & 5] has published two bulletins dealing with what he calls "crown-rot." He came to the conclusion that practically all of the injury at the collar of trees was due to winter injury. In view of our experience in Pennsylvania, where collar-blight is so prevalent, and of Whetzel's observations in New York, which confirm our work, it seems extremely improbable that all the collar diseases described by Grossenbacher can be due to winter injury. At least, until more thorough investigations are carried out with regard to the possible presence of parasites in the cankers which he describes and illustrates, considerable doubt will be attached to his conclusions.

R. E. Smith[6] refers to collar-blight in California as occurring in orchards where fire-blight is present and where, as he says, "it appears that certain roots have been badly injured and that the portions affected above ground correspond with such roots."

Jackson[7] refers to the prevalence of collar-blight in Oregon stating that, "it is this form of the disease that causes many trees to be killed outright."

Giddings[8] reports that collar-blight is one of the most serious diseases of the apple in West Virginia.

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[2] Selby, A. D., Ohio Agric. Exp. Sta. Bull. 121:15. 1900.

[3] Whetzel, H. H., Blight Canker of Apple Trees. 13th Ann. Rept., New York Dept. Agric. **1905**:125.

[4] Grossenbacher, J. G., N. Y. Agric. Expt. Sta. Technical Bull. 12. 1909.

[5] Grossenbacher, J. G., N. Y. Agric. Expt. Sta. Technical Bull. 23. 1912.

[6] Smith, R. E., and Smith, E. H., California Plant Disease. Cal. Agric. Exp. St. Bull. **218**:1155. 1911.

[7] Jackson, H. S., Diseases of Pomaceous Fruits. Biennial Crop Pest and Hort. Report. **1911-12**:245. 1913.

[8] Giddings, N. J., The Rept. W. Virginia Dept. Agric. **29**:15-19. 1913.

Pickett[9], in Illinois, says that "the most serious of these hold-over cankers in apple trees are probably the large ones which are found on the larger branches, in the forks of the branches, and, in certain cases of 'collar-rot', in large areas on the trunks just above the surface of the ground." This disease undoubtedly has been referred to in other literature pertaining to fire-blight but not in such definite terms as to call for citation.

ECONOMIC IMPORTANCE.

So far, collar-blight appears to be almost exclusively a disease of the apple tree, but in 1913 there was one report from Bucks County of its occurrence upon pear trees where it was even more serious than upon the apple. There would seem to be no reason why other hosts of the fire-blight organism should not be attacked under conditions similar to those in which the apple is susceptible.

At the present time collar-blight is considered one of the most serious diseases of apple trees in Pennsylvania, not because of its

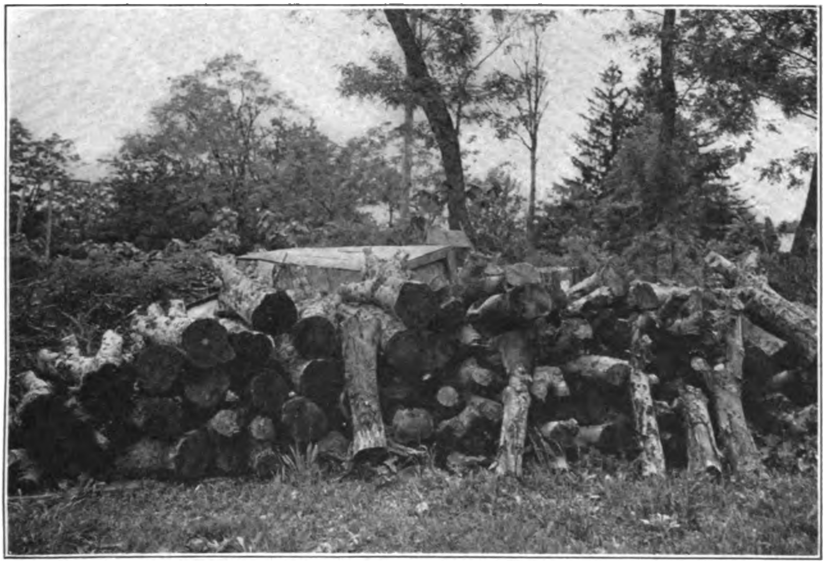

Fig. 1—Collar-blighted trees removed from a single orchard. Should be utilized immediately for fuel or burned.

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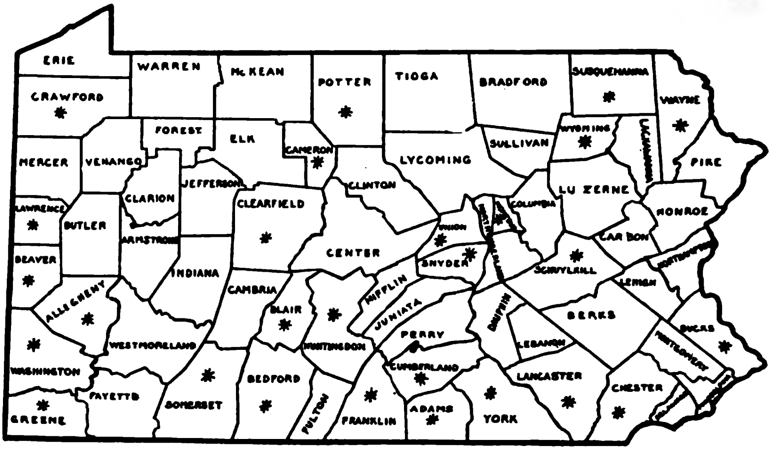
[9] Pickett, B. S., The Blight of Apples, Pears, and Quinces. Illinois Agric. Expt. Sta. Circular 172:5. 1914.

liability to reduce the proceeds from any one crop to a considerable extent, as some of the fruit-attacking fungi often do, but because of its attack upon the trees at the most critical period of their life, and the difficulty of treatment and the control of its further spread. Some large apple growers in the State have lost so many trees from this cause that they are much discouraged about apple growing and are on the point of replacing their apples with peaches (Fig. 1).

The loss from collar-blight alone in Pennsylvania is conservatively estimated at two per cent. annually.

DISTRIBUTION OF COLLAR-BLIGHT IN PENNSYLVANIA.

A rather careful survey was made in the fall of 1913 to secure information on the occurrence of collar-blight in this State. To this there have been added the reports received in 1914. The accompanying map will show the distribution of the disease by counties, a star representing its occurrence in a county. The disease appears to be most prevalent in our larger apple-growing sections, as might be expected. Undoubtedly it is present in counties not reported here and may be expected to occur wherever the apple is grown to any considerable extent. It is to be noted that in 1910, when a study of the disease was first taken up at this Station, it was known definitely to occur in only five counties. It is represented now in 27 counties, according to the accompanying map.



SYMPTOMS.

The early symptoms of collar-blight are usually evident during the growing season by a more or less unhealthy appearance of the foliage. The leaves appear yellowish and smaller on one or more of the large limbs as contrasted with normal foliage. When infected areas on the trunk progress slowly and extend through two or more seasons, the foliage, especially on that side of the tree affected, is rather sparsely developed (Fig. 2). Since this effect on the foliage is rather gradual, it does not result in the wilting or drying of the leaves in contrast to fire-blight infection of twigs. The ultimate effect on the foliage in all cases is the premature falling of the leaves.

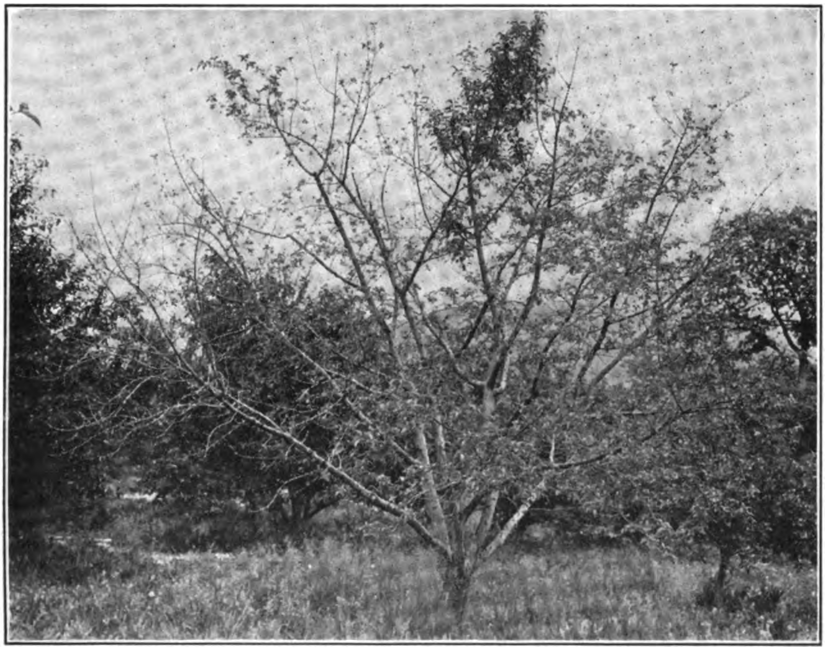


Fig. 2—Typical appearance of foliage on tree affected with Collar-blight.

The general yellowing of the foliage facilitates the recognition of infected trees during the growing season. On examination of the collar of such trees there will be found a sunken area of variable size depending upon the time which has elapsed since infection took place. Newly infected areas are not sharply marked off as in the more advanced cases. The disease progresses rapidly until midsummer when its development is arrested. During the next season activity is renewed, the attack often resulting in the complete girdling and subsequent death of the tree (Fig. 3). The girdling at the collar may be said to be the usual method of development but often, under certain favorable conditions not yet ascertained, the blight may extend very rapidly up one side of the trunk into the branches, and thus cause sudden death (Fig. 4). In some cases it has been observed to extend downwards, thus affecting the lateral roots for some distance.

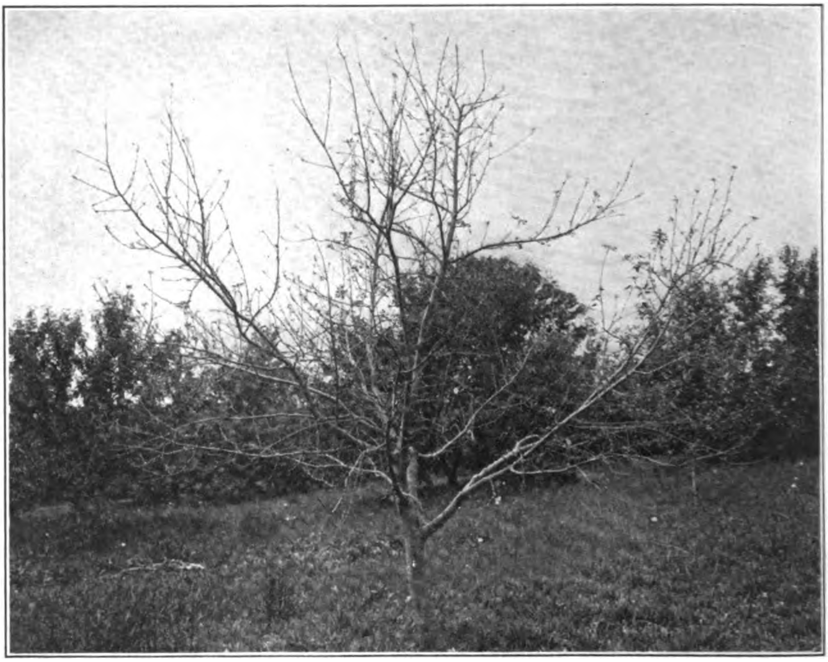


Fig. 3—Symptoms of Collar-blighted apple tree in late stages.

Usually it is not until the second season of infection that the characteristics of the disease above the ground are clearly defined. A distinct line of demarcation separates the normal tissue from the lesions, which appear to be water-soaked and browned, eventually separating from the sap-wood (Fig. 5). The diseased tissue emits a sour odor and often small milky drops exude which consist of masses of bacteria. Pure cultures of *Bacillus amylovorus* have often been isolated from these exudations. The sap-wood becomes browned and later blackened.

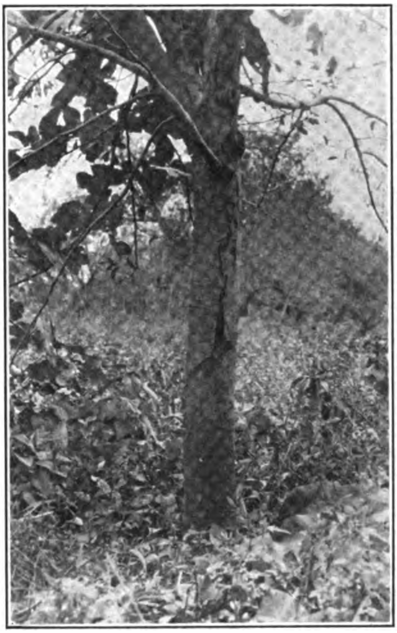


Fig. 4—Collar-blight, showing rapid progression up the trunk.

During the second season the foliage is usually scanty, and it is common for such trees to blossom heavily and to set fruit which develops under size and inferior in quality with a tendency to fall early. Attempts at healing which have prevented complete girdling have been observed often. In some cases of apparent normal healing, further extension of the infected area has been caused by borers working from the old lesions through the callus into the uninfected region.

COLLAR-BLIGHT VERSUS "WINTER INJURY" AND "ROOT-ROT."

Collar-blight is distinctly different from what has been called "winter injury" and from some forms of "root-rot" which often

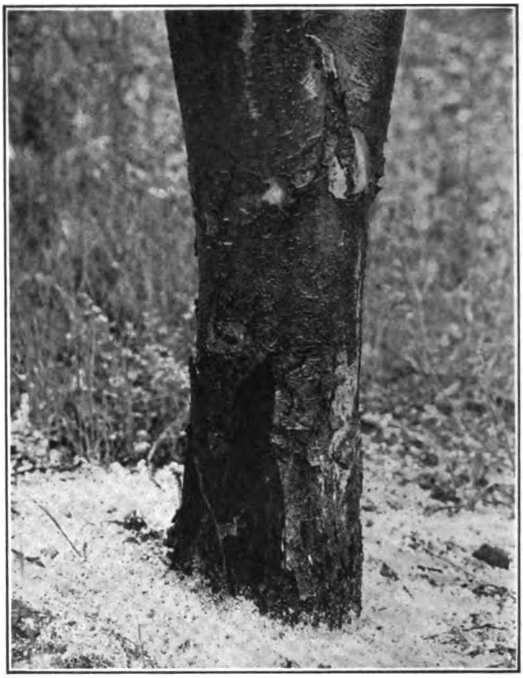


Fig. 5—Typical Collar-blight, showing loosening of bark and blackening of sap-wood.

extend above the ground. In "winter injury" there is usually a sudden killing of the bark and cambium by freezing. Weather conditions which cause it are successive periods of freezing and thawing. "Winter injury" usually occurs on the southwest side of trees. It is noticeable at the beginning of the growing season, but in no case is there the progressive dying such as we find in the collar-blight. Oftentimes the winter-injured bark splits, loosens, and rolls back from the sap-wood and the latter is discolored, but there is not the water-soaked appearance of the diseased bark that is observed with collar-blight. In the case of this disease there is a distinct progressive death of the bark and cambium which is not usually observed until midsummer.

Root-rot may be secondary to "winter injury" and collar-blight or infection may first take place in wounded roots and the disease gradually work upward, killing the bark above ground in a manner somewhat similar to collar-blight. The appearance of whitish mycelial growth on the affected roots will serve to distinguish this disease from collar-blight or "winter injury." A softening of the wood occurs also in the case of root-rot. Conclusive evidence of root-rot is furnished when the fruiting bodies or mushrooms appear above the ground around the base of the trees in midsummer or later.

THE CAUSE OF COLLAR-BLIGHT.

The junior author has carried out continued investigations with regard to the cause of collar-blight as distinguished from "winter injury" and root-rot. Only one parasitic organism has been isolated from these cankered areas. This was *Bacillus amylovorus (Burr) deToni,* the cause of the well-known fire-blight disease of pomaceous trees. *Sphaeropsis malorum* was found growing frequently in the blighted bark and even, in some cases, down on the dead roots below the ground. Repeated inoculations with this fungus always have failed to produce a canker, and it is believed to be only a saprophyte on the bark following collar-blight as regularly as it does twig and canker-blight.

Bacillus amylovorus has been inoculated directly from pure culture and from diseased bark into the collar and roots of young apple trees, and typical cases of collar-blight have resulted. A report of inoculation work has been made elsewhere[10] by the authors. More work remains to be done in order to determine the optimum time of infection and the active period of development of the organism at the collar, but the authors regard the fire-blight organism as the cause of a majority of the collar diseases of the apple tree in Pennsylvania.

VARIETIES OF APPLES SUSCEPTIBLE TO COLLAR-BLIGHT.

The following data, bearing on the apparent resistance or susceptibility of apple varieties to collar-blight, have been compiled from reports and observations in the State. Only where there are two or more reports on a variety does that variety appear in the list.

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[10] **Orton, C. R., and Adams, J. F. Collar-Blight of Apple Trees in Pennsylvania, (abstract) Phytopathology 4:43. 1914.**

	Variety	Number of Times Reported Resistant	Number of Times Reported Susceptible
1	Baldwin	8	8
2	Ben Davis	2	7
3	Fall	1	2
4	Grimes Golden	2	12
5	Haas	2	..
6	Maidens Blush	..	2
7	Northern Spy	3	2
8	Pewaukee	..	2
9	Fallawater	..	2
10	Rhode Island Greening	4	2
11	Russet	1	1
12	Smith Cider	..	2
13	Smokehouse	2	1
14	Sutton	1	1 bad
15	Twenty Ounce	..	2
16	White Pippin	2	..
17	Wolf River	2	..
18	York Imperial	..	14

Judging from the work and observations by the writers, as well as from the information noted in the above table, it would seem that scarcely any variety can be said to be wholly resistant to collar-blight. On the other hand, Grimes, Baldwin, and York Imperial have been reported as diseased frequently enough to indicate their susceptibility. Selby[11] states that in Ohio, Grimes, Maidens Blush, Sutton, Tompkins King, and Yellow Transparent are the most susceptible to "collar-rot." Ben Davis and Baldwin are moderately susceptible in Ohio.

Giddings says that in West Virginia, York Imperial usually appears to be quite resistant, an observation not borne out by reports in Pennsylvania.

PREDISPOSING FACTORS.

Judging from observations supplemented by the experience of orchardists in the State, the authors have concluded that there are five factors of some importance favoring the appearance of collar-blight. These are fertilization, mulching, cultivation, root-grafting, and the age of trees.

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[11] Selby, A. D., Ohio Agric. Exp. Sta. Circular 133. 1913.

It has been demonstrated by Stewart[12] and others that the twig-blight form of fire-blight is much more severe on trees which have received stable manure or heavy applications of other highly nitrogenous fertilizers. The same holds true, according to our observations, of collar-blight and this is supported by the experience of many commercial growers who find that this trouble is much more prevalent where heavy and continuous applications of such fertilizers are used.

Mulching also is conducive to the appearance of collar-blight. It has been noticed frequently that orchards where heavy mulching was regularly practiced, especially if accompanied by fertilization, were more seriously affected by this disease than were orchards where this system was not employed. Both fertilization and mulching are conducive to rapid growth and to the development of more succulent inner bark where the blight organism works chiefly. These factors are undoubtedly important in rendering the host plant more susceptible to collar-blight as well as to the other forms of fire-blight.

Cultivation has been thought by some growers to be an important factor in the appearance and spread of the disease. This has not been proved, but it seems probable that cultivation may be indirectly responsible for the spread of collar-blight, since wounds made at the collar and on the roots by the cultivator may frequently serve as a means of entrance for the organism.

From reports received it would appear that the system of propagation by root-grafting is conducive to the frequent appearance of collar-blight. Top-worked or budded trees on the other hand do not seem to be so commonly attacked. It seems probable that when an imperfect union results from root-grafting an easy means of entrance is afforded the blight organism. The use of blight-susceptible stock may be a further factor in the severity of collar-blight.

The statistics compiled from various parts of the State show that the average age of trees at the time of infection by collar-blight is between 12 and 13 years. The complete range for cases observed was from 7 to 20 years with few exceptions. These data are important for they show that trees are most likely to be attacked at the time when they are most valuable. Other workers on collar-blight have made the same observations.

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[12] **Stewart, J. P.** Report Pennsylvania Exp. Sta. **1910-11**:467. 1912.

METHODS OF DISSEMINATION.

Inasmuch as the other forms of fire-blight, such as blossom-blight, twig-blight, and fruit-blight, as well as canker-blight in some cases, are spread by insects, it seems logical to suppose that collar-blight also may be spread by such agents.

In 90% of the reports and observations made on collar-blight, apple-tree borers were associated with the disease at the collar. Whether they are the direct carriers of the blight bacillus or are only secondary has not been determined as yet. Their presence there so frequently is suggestive, however, and they are certainly an important factor to be reckoned with. Whetzel[13], in New York, has also observed borers as being associated with collar-blight. As Whetzel suggests, it is possible that the borers serve primarily to open a place of entrance and that the bacteria are carried to the collar by other insects attracted there by the sap exuding from punctures made by borers.

Jones [14], in Ontario, Canada, has shown conclusively that the "fruit-bark beetle," *Scolytus rugulosus*, is frequently the direct carrier of *Bacillus amylovorus*, which causes canker-blight on the limbs and trunks of pear trees. The same writer[15] has shown also that *Aphis Pomi* and *Schizoneura lanigera* are responsible for 50% of the twig-blight on apple trees before the blossoming period and practically all cases after the blossoming period.

The woolly aphis, *Schizoneura lanigera*, was reported present in Pennsylvania in all cases where collar-blight was present in the orchard, and, according to the observations of the authors, it is commonly found in the blighted areas. It is quite possible that this insect may be the carrier of the blight organism to the wounds made by borers, as it is known that the aphides commonly congregate wherever any exudations of sap occur. Whether they also may cause collar-blight infection independently of previous wounds is not known, but such may be the case. There seems to be good evidence to show that insects of one kind or another may be responsible for a considerable amount of collar-blight.

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[13] Whetzel, W. H. Cornell Agric. Exp. Sta. Bull. 236:118-110. 1906.

[14] Jones, D. H. *Scolytus rugulosus* as an Agent in the Spread of Bacterial Blight on Pear Trees, Phytopath. 1:149-151. 1911.

[15] Jones, D. H. Ann. Rept. Ontario Agric. Col. and Exp. Farm. 35:125-130.

Other means of dissemination may be the tools used in the removal of borers; careless cultivation resulting in wounds at the collar; the presence of suckers at the roots of trees which are frequently blighted and by means of which the bacterial organisms may gain entrance to the collar (Fig. 6); the removal of suckers from the base of trees during the growing season and neglect to protect the cut surface which remains; and the injuries caused by mice, rabbits, and such animals.

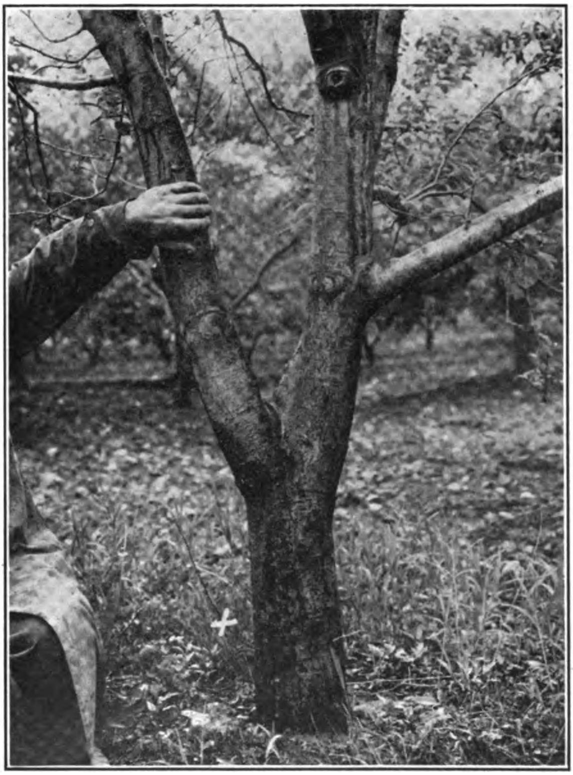

Fig. 6—Collar-blight originating through the sucker at left marked by an X.

TREATMENT AND METHOD OF CONTROL.

From the nature of the causal organism, and the long-tried methods for its control by surgical treatment, it has seemed that the application of such methods might be of practical use in treating trees blighted at the collar. On this assumption the junior author carried out a series of experiments in 1912, to ascertain whether collar-blight might be successfully checked by cutting out the diseased areas. Trees in all stages of the blight were chosen and from the results of these experiments it would seem possible to cut out collar-blight with good chances of saving the trees, provided they are not more than half girdled. If more than half

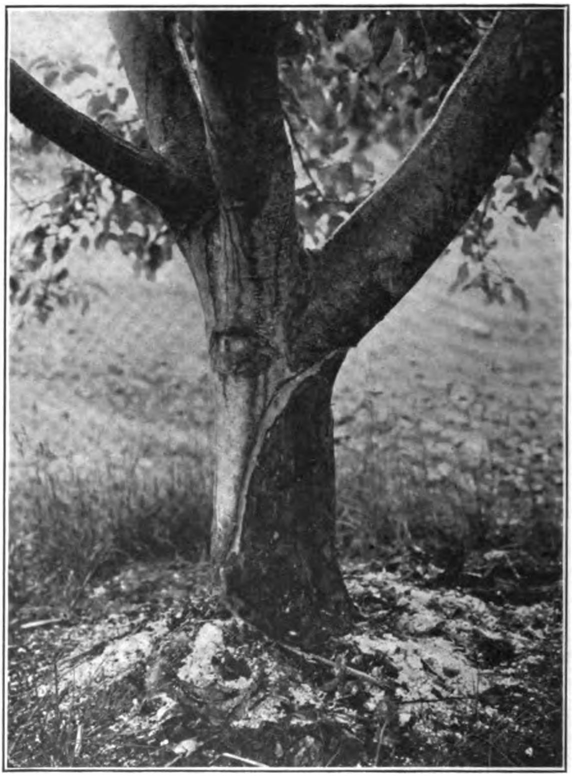

Fig. 7—Typical Collar-blight, showing proper method of cutting back into healthy bark before treating with paint.

girdled, it hardly seems advisable to attempt to save the tree unless bridge-grafting can be resorted to advantageously.

It is also important to thin the fruit out well on treated trees, in order that the maximum amount of food may be used by the tree to form callus growth and thus hasten recovery.

If the diseased trees have passed beyond the period favorable for surgical treatment, they should be removed at once, as they are likely to be a serious source of infection to other trees in the orchard. As previously indicated, it seems probable that almost any sort of boring or sucking insect may carry the blight organism from such trees to others, especially such as have been weakened

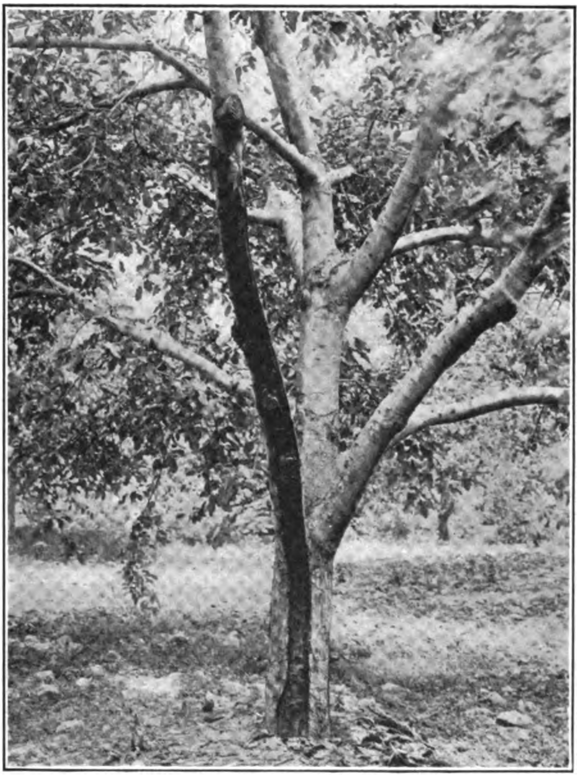

Fig. 8—A case of Collar-blight which progressed rapidly up into the limb. Properly cut out and treated.

by some cause, and there establish new infection centers. It is, therefore, essential not only to remove immediately trees which are hopelessly diseased, but to be very careful during a search for borers to avoid carrying the blight organisms on the tools. Approved methods of insect control, especially with regard to borers and woolly aphis, would appear also to be important.

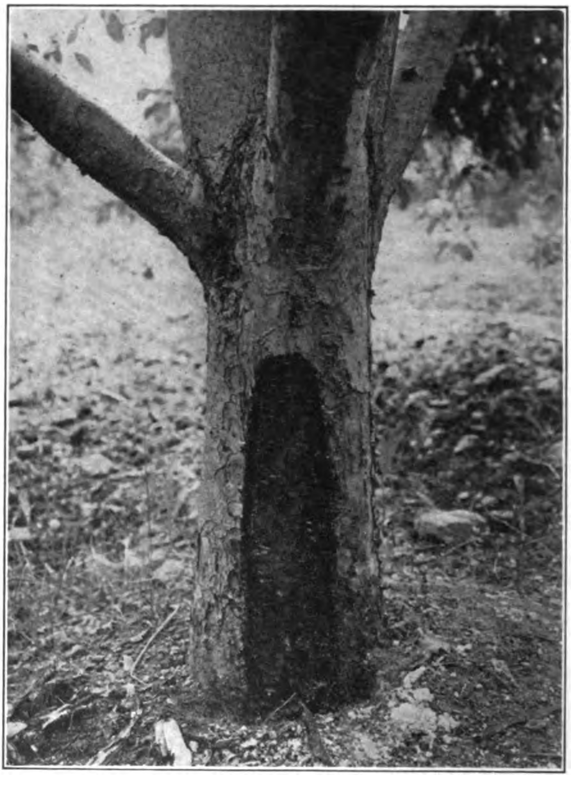

Fig. 9—Showing a Collar-Blighted area properly cut out and treated with asphaltum.

For proper cutting out of the diseased areas a heavy chisel and mallet are desirable. The soil should be removed from about the diseased collar and roots. All diseased roots should be removed from the tree as completely as practicable.

Cut to a depth of at least 1 to 2 inches into the healthy, green bark surrounding the diseased spot, being careful to remove all infected tissue (Fig. 7). Sterilize the surface of the wound with corrosive-sublimate (bichloride of mercury) 1:1000 strength, or with concentrated lime-sulphur solution. The wound should be allowed to dry thoroughly, after which a thick coat of white lead and linseed oil should be applied. After the latter has dried, the soil should be carefully replaced about the collar. In the treatments of wounds, different asphaltic compounds were experimented with and some proved very successful. Owing, however, to the injurious effects of some asphaltic compounds, the authors hesitate to recommend their use until their safety has been established by more complete experiments on fruit trees. A coat of white lead seems preferable. Figures 8 and 9 show trees successfully treated and painted with asphaltum.

FIRE-BLIGHT AND OTHER RELATED FORMS OF BLIGHT

DIFFERENT FORMS OF FIRE-BLIGHT.

There are four other forms of blight caused by the same organism *(Bacillus amylovorus)* that causes collar-blight. These

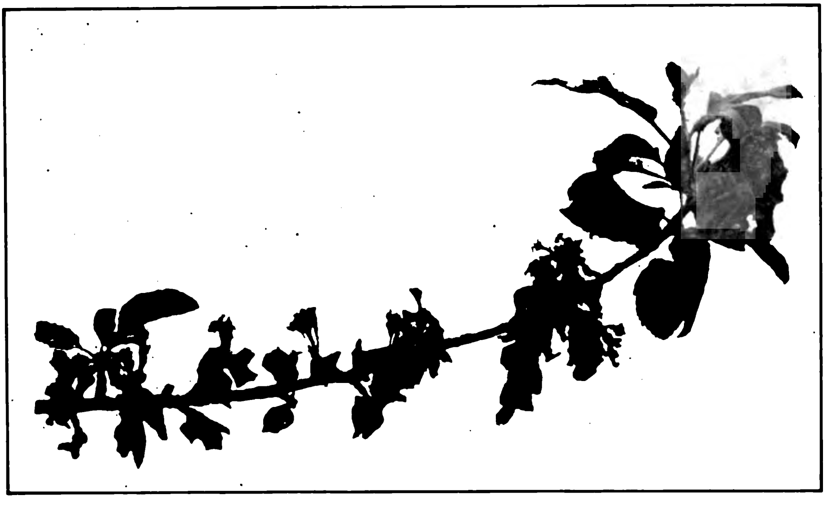

Fig. 10—A typical case of Blossom-blight in early stages.

forms are known as blossom-blight, fruit-blight, twig-blight, and canker-blight. Apple, pear, and quince trees are especially susceptible.

Blossom-blight is evident by a general browning of the flower clusters, which eventually become entirely blackened (Fig. 10). Such infection often extends downward through the fruit-spurs into the twigs and frequently develops canker-blight. This form of fire-blight was especially serious throughout Pennsylvania during the spring of 1915.

Fruit-blight usually appears any time after the fruit starts to develop until it is at least one inch in diameter. It usually starts as brownish or much darkened areas, which progress rapidly until the entire fruit is involved (Fig. 11). The blighted fruits are usually covered with bacterial exudations that make them sticky to the touch. This form of blight often accompanies twig-blight.

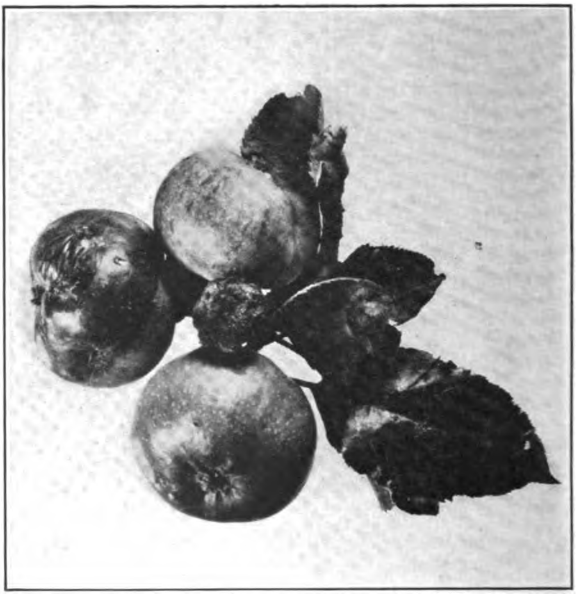

Fig. 11—Fruit-blight. Note especially the apple at left showing characteristic appearance.

Twig-blight is the most prevalent form. Its presence is indicated by the blighting of the twigs from the tips downward. The leaves turn brown and cling strongly, giving badly blighted trees the appearance of having been scorched by fire, hence the term fire-blight. The young bark and sap-wood are blackened.

Canker-blight is usually the result of the bacteria working into the larger limbs from the infected twigs, fruit-spurs, or water-sprouts (Fig. 12). Injury by mechanical means also may permit the entrance of the organism. Injury by insects, such as the fruit bark-beetle, or by birds may possibly be responsible. The cankered areas are at first small in outline, but may later progress into a long, extended canker and often completely girdle the limb, so that the

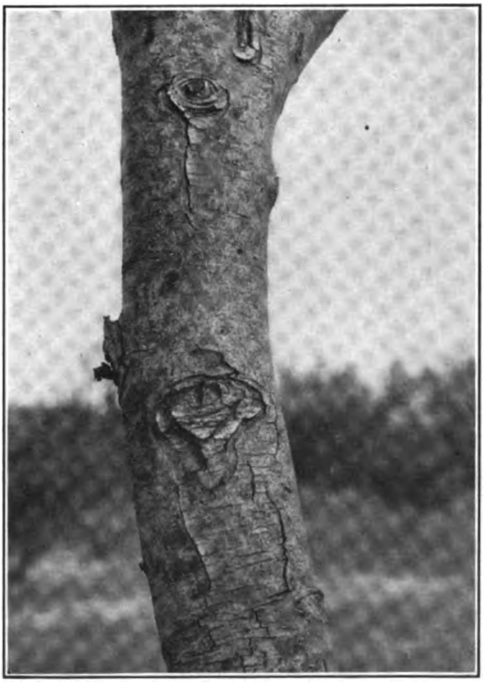

Fig. 12—Newly formed Canker-blight. Organism entered trunk through spurs.

outer parts of the limbs are entirely killed. These cankers are usually typical, being much roughened or depressed areas, which are sharply marked off from the healthy tissue by a line of demarcation. They are in most respects similar to collar-blight in mode of development. These blight cankers on the limbs of the upper part of the trunk are frequently referred to as "hold-over cankers." The bacteria remains alive through the winter in the tissue at the margin of these cankers, and in the spring, when the sap becomes active, they renew their activity. Bacterial exudations are usually emitted and different insects feed on this ooze and then visit the blossoms, fruits or twigs, and rapidly spread the infection. To reduce the spread of fire-blight it is essential to remove these cankers.

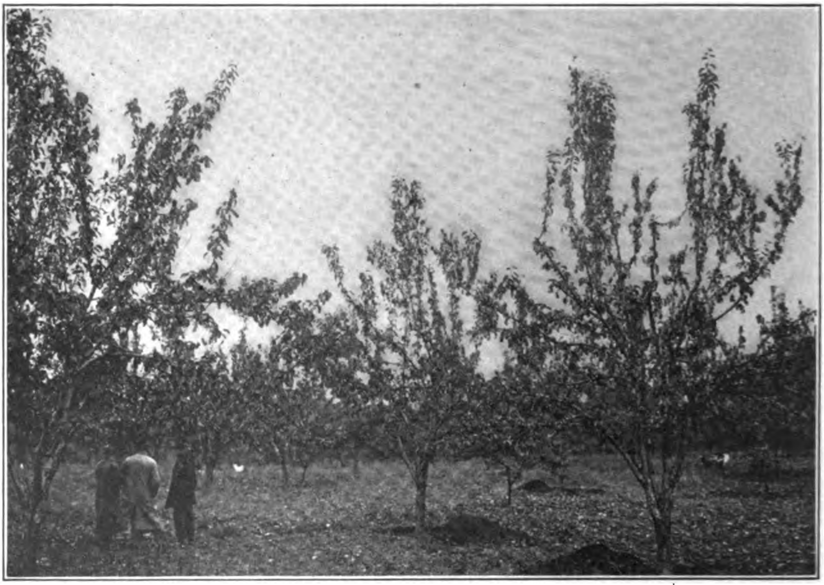

Fig. 13—Showing pear trees severely infected with Fire-blight.

Warm, moist weather favors the development of blight and makes the younger growth more susceptible. Fire-blight can be controlled by giving careful and prompt attention to the removal of all infected parts. Infected twigs and water-sprouts should be cut at least six inches below any sign of bark discoloration and all cuts should at once be disinfected with corrosive sublimate (bichloride of mercury) at the strength of 1:1000 parts of water or about 1 tablet to one pint of water. All canker-blight should be cut out and the cuts disinfected and painted over with white lead and linseed oil. This will protect the cut surface against infection by other organisms and facilitate the formation of callus growth.

In order to eliminate or to reduce the blight to a minimum, careful inspection must be resorted to at least every week from blooming time until the fruits are one-third to one-half grown, and any blighted parts, however small, removed at once. Only by such careful inspection and removal, and the co-operation of all fruit growers in the locality, can blight be controlled.

Blossom-blight is spread chiefly by nectar-gathering insects, such as bees, and for that reason this form of fire-blight is most difficult to control. The insects chiefly concerned in spreading the twig and fruit blight are probably aphides and the red bugs, and the control of such pests should greatly reduce the spread of these forms of fire-blight. Many of these insects may be controlled by using the combination spray of one pint 40% nicotine solution to each one hundred gallons of diluted or self-boiled lime-sulphur. The general plan for the first two sprayings of apples and pears may be followed. The first application should be made when the blossoms are just showing pink and a second when the petals are two-thirds fallen.

It is also worth while to give attention to such cultural methods as will tend to increase the disease-resistance of the trees. A moderate well-hardened growth is not as susceptible as either a large and succulent growth or a weak and feeble growth. The results of experiments have shown that attention to the character of the growth is frequently sufficient to control the forms of fire-blight.

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